FUNDAMENTAL INVESTIGATIONS ON CORROSION DETERIORATION OF STEEL STRUCTURES(Dissertation_全文)

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CITATION:

RUNGTHONGBAISUREE, Somkiat. FUNDAMENTAL INVESTIGATIONS ON CORROSION DETERIORATION OF STEEL STRUCTURES. 京都大学, 1991, 工学博士

ISSUE DATE:

1991-03-23

URL:

https://doi.org/10.11501/3053006

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ACKNOWLEDGMENT

The author wishes to thank Professor Naruhito SHIRAISHI of Kyoto University for his general guidance, valuable advice and criticisms throughout the dissertation. The author also wishes to extend his sincere thanks to Associate Professor Masaru MATSUMOTO of Kyoto University for his supervising this dissertation, encouragement, and patience throughout the author's academic activities.

Thanks also extends to Dr. Hiromichi SHIRATO of Kyoto University for his valuable advice, Mr. Takashi OKAMURA for his assistance in surveying until data analysis, and Mr. Hideaki SHIMANO for his assistance in surveying.

However, if there were not the collaboration from many administrations, the present research could not have been developed so well. In this respect, the following administrations are greatly acknowledged.

1 Hanshin Expressway Public Corporation
2 Hiroshima Prefecture
3 Hitachi Zosen Corporation, Nichizo Tech Inc.
4 Keihan Electric Railway
5 Kyoto City
6 Okinawa Development Agency
7 Okinawa Prefecture
8 Osaka City

CONTENTS

1 INTRODUCTION

1.1 BACKGROUND OF THE RESEARCH

Corrosion deterioration of steel structures has become an important topic among engineers and researches since it was found that corrosion can be the cause of the structural failure.[1),2)] It was reported that economic loss due to corrosion deterioration in the United States of America in 1950 was about 5.4 billion dollars.[3)] For structural steel bridges, the examples of structural failures due to corrosion deterioration are the failure of Clapham Junction Bridge in 1965[4)] and the collapse of well-known Point Pleasant Bridge in 1967.[5)-9)]

A lot of bridges have been reconstructed due to corrosion deterioration such as Marlow Suspension Bridge over the River Thames at Marlow[10)] and Railway Bridge D29 in London.[11)] In Japan, it was reported that about 64% of bridge replacements were due to corrosion deterioration.[12)-15)] In the United States of America, the annual loss for highway and railway bridges due to corrosion deterioration was reported as 30.4 million dollars.[16)] These events show the importance of the research on the topic of corrosion deterioration of steel structures.

Steel bridge is selected as a representative steel structure in this study. Research on corrosion deterioration of steel bridges begins from the research on corrosion behavior of bare steel and the research on service life of paint. Up to the present there were very few investigations on these topics. For corrosion behavior of bare steel, the well-known model for predicting long-term corrosion is the model of Horikawa.[17)] However, this model gives a good representation of long-term corrosion of bare steel only when exposure time is far from zero. When exposure time equals or close to zero, this model cannot give a accurate proof that corrosion must be zero when exposure time equals zero. Another model that gives a good representation of corrosion behavior of bare steel for all exposure time is necessary.

As for service life of paint, it has been previously determined from the regression equations of paint film deterioration. However, regression equations of paint film deterioration used by former researches cannot give accurate proof that there must be no deterioration of paint film when exposure time equals zero. These regression equations must be improved in order to get a good representation of paint film deterioration.

The model for predicting corrosion of painted steel bridges has been previously proposed by Michiura.[18)] In this model, corrosion of painted bridge members is determined based on corrosion behavior of bare steel from the model of Horikawa and service life of paint from the models of former researchers. However, corrosion behavior of bridge members varies depending on structural details. The difference in the rate of corrosion among bridge members was not considered in this model. Therefore improvement in this model is required.

For the effect of corrosion on the strength of bridge members and the bridge safety, the investigations for unpainted bridge members have been done recently by Kayser.[19)-21)] Capacity loss of unpainted bridge members was determined based on the assumed corrosion rate of bridge members. In the case of painted steel bridges, there is still no investigation on this topic up to present.

1.2 OUTLINE OF THE RESEARCH

The main object of this research is to clarify the corrosion deterioration characteristics of structural steel bridges. The first step to understand the corrosion behavior of steel bridges is to understand the corrosion behavior of steel materials. Next is to clarify the deterioration behavior of paint, and to determine the service life of paint. Corrosion of painted steel materials can be determined based on these results. After that, corrosion deterioration behaviors of structural steel bridges are determined based on corrosion behavior of painted steel materials and the results of bridge survey.

The model for determining the effect of corrosion on the strength of bridge members and the model for determining the safety of existing bridges will be developed. The methods for protecting bridges against corrosion as well as the model for determining the efficiency of maintenance system will be proposed. The outline of the research in each chapter is as follows:

Chapter 2:

The main object of this chapter is to clarify the corrosion process of bare steel. Environmental factors that greatly influence on the rate of steel corrosion will be investigated. Two groups of regression equations for predicting corrosion at certain exposure times as a function of environmental factors will be determined. Group one is for steel materials that are exposed to rain. The other group is for steel materials that are not exposed to rain. A model for predicting long-term corrosion of bare steel will be proposed.

Methods for protecting against corrosion, steel materials which are exposed to the atmosphere will be investigated.

Chapter 3:

The main object of this chapter is to determine the service life of paint for structural steel bridges. Data of paint film deterioration for each bridge member collected from existing bridges by means of rating number. Regression equations of paint film deterioration and service life of paint are determined based on these data. Main factors that influence the rate of paint film deterioration are investigated.

Chapter 4:

The main object of this chapter is to clarify the corrosion deterioration characteristics of structural steel bridges. First, data of corrosion deterioration of bridge members are collected from existing bridges, and expressed by means of rating number of steel corrosion. Plate thickness of corroded bridge members and scrap materials are measured in order to determine the relation between rating number of steel corrosion and corrosion depth.

Data of corrosion depth in terms of rating number of steel corrosion are converted to corrosion depth. From this result, the relationship between corrosion depth of bridge members and exposure time of steel surface after the expiration of paint life will be determined for each bridge member and environment.

The methods for predicting uniform corrosion and local corrosion of painted steel materials are proposed. Corrosion depth of painted steel materials is determined based on corrosion behavior of bare steel and service life of paint. Corrosion depth of painted steel materials is determined for the same atmospheric condition of each bridge member. These results and the results of a bridge survey are used for calibration in order to determine the corrosion ratio, which represents the difference in the rate of steel corrosion between normal painted steel material and each bridge member. After that, corrosion of bridge members can be predicted based on corrosion behavior of bare steel, service life of paint, and corrosion ratio.

The effect of corrosion on the strength of bridge members is determined in terms of stress ratio, which is the ratio of stress value on a corroded section of bridge members to stress value on an original uncorroded section. Maximum and/or local corrosion depth which has a more significant effect on the strength of bridge members than uniform corrosion is converted to effective corrosion depth before determining its effect on the strength of bridge members. This stress ratio shows the percent of stress level in bridge members increasing due to corrosion on the assumption that the bridge has to resist the same amount of load before and after corroding. The invert of stress ratio shows the percent remaining in stress capacity of bridge members due to corrosion if the stress that occurs on bridge members is limited to the same value before and after corroding.

Simple but effective methods for determining the safety of existing bridges will be developed. The safety of existing bridges due to corrosion deterioration is determined in terms of deteriorating index. Two methods for determining the safety of existing bridges are developed based on the field data of corrosion deterioration of bridge members. Method one is to evaluate the global deterioration of the existing bridges by means of overall deteriorating index. The other is to evaluate the local deterioration of the existing bridges by means of local deteriorating index.

Chapter 5:

Protection of steel bridges against corrosion will be investigated in this chapter. The aim of this investigation is to draw attention to design considerations and maintenance of bridges against corrosion.

A simple model for determining the efficiency of maintenance systems will be developed. A questionnaire of bridge maintenance and inspection was sent to 28 administrations that have steel bridges in supervision. The results of the questionnaire are used for determining the efficiency of the maintenance systems. The efficiency of the maintenance systems was determined in terms of maintenance index. Maintenance index of good maintenance systems is higher than maintenance index of poor maintenance systems.

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2 CORROSION CHARACTERISTICS OF STEEL MATERIALS[1)-6)]

2.1 INTRODUCTION

There is no steel found on earth in the form of a pure mineral like gold. Steel is an artificial substance made from iron ore that is stable in the form of oxide. Since steel is not stable in nature, it tends to change to a stable form of oxide whenever it is exposed to the atmosphere, water, or soil, and this is corrosion. Corrosion is the destructive attack of a metal by chemical or electrochemical reaction. Deterioration by physical causes is not called corrosion, but is described as erosion, galling, or wear. From the point of view of structural performance, corrosion is a potential cause of failure by virtue of the higher levels of stress resulting from reduced section.[7)] In order to achieve a long service life of steel structures, proper protection methods of steel against corrosion are necessary. This requires a good understanding of corrosion mechanism of steel materials.

2.2 CORROSION MECHANISM OF STEEL MATERIALS[8)-10)]

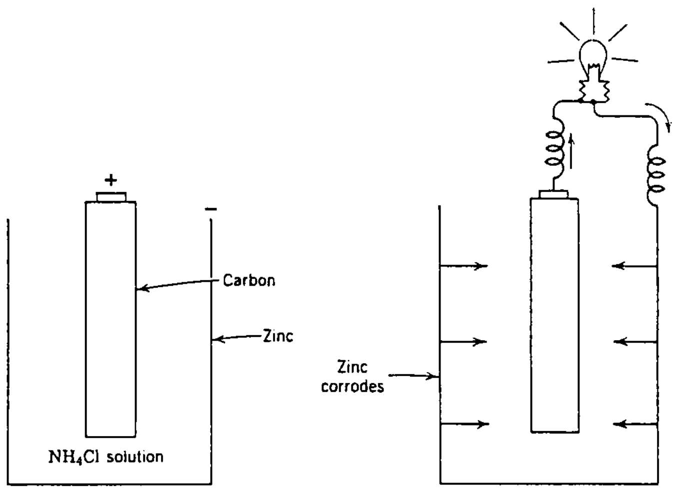

Fig. 2.1 Dry cell[8)]

As mentioned above, corrosion processes are chemical or electrochemical reaction. In aqueous media, the action is similar to that taking place in a cell made up of a center carbon electrode and a zinc cup electrode separated by an electrolyte consisting essentially of NH_4Cl solution (Fig. 2.1). At the carbon electrode (positive pole), chemical reduction occurs, and at the zinc electrode (negative pole) oxidation occurs, metallic zinc being converted into hydrated zinc ions. The greater the flow of electricity through the cell, greater is the amount of zinc that corrodes.

On an open circuit, zinc can corrode slowly. The slow consumption of zinc on an open circuit is accounted for largely by the activity of minute impurities, like iron, embedded in the surface of zinc. Any metal surface, similar to the situation for zinc, is a composite of electrodes electrically shot-circuited through the body of metal itself (Fig. 2.2). So long as the metal remains dry, corrosion is not observed. But on exposure of the metal to water or moisture, local-action cells are formed and are accompanied by chemical conversion of the metal to corrosion products.

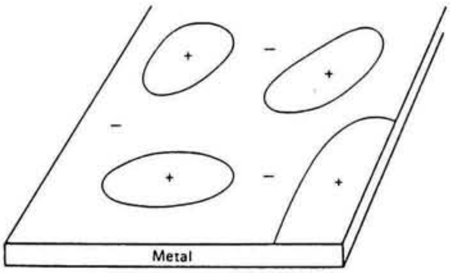

Fig. 2.2 Metel surface enlarged, showing schematic arrangement of local-action cells[8)]

In the case of pure metal such as iron or steel exposed to the atmosphere, local-action cells are also set up when there are variations in the environment or in temperature. For iron or steel, the negative electrodes are commonly portions of the iron surface itself covered perhaps by porous rust (iron oxides), and positive electrodes are areas exposed to oxygen (Fig. 2.3). The amount of oxygen reaching the metal that is covered by rust is less than the amount that contacts other portions where permeable coating is thinner or absent. The positive and negative electrode areas interchange and shift from place to place as the corrosion reaction proceeds.

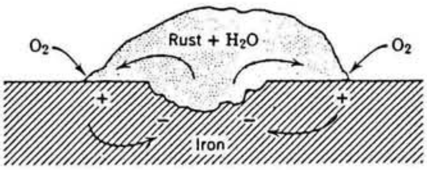

Fig. 2.3 Differential aeration cell formed by rust on iron[8)]

When there is water at the steel surface, the following reactions take place:

$$H_2O + H_2O \longrightarrow 2HOH \qquad (2.1)$$

$$Fe + 2HOH \longrightarrow Fe(OH)_2 + H_2 \qquad (2.2)$$

Ferrous hydroxide ($Fe(OH)_2$) forms next to the steel surface. At the outer surface of the oxide film, ferrous hydroxide converts to ferric hydroxide by dissolving oxygen, in accord with

$$2Fe(OH)_2 + \frac{1}{2}O_2 + H_2O \longrightarrow 2Fe(OH)_3 \qquad (2.3)$$

Ferric hydroxide takes place at the outer surface of the oxide film, and the corrosion reaction proceeds.

2.3 FACTORS INFLUENCING THE RATE OF STEEL CORROSION

There are many factors influencing the rate of steel corrosion. These factors can be classified into two groups. Group one is inner factors such as steel components, while the other group is outer factors such as environmental factors. Only environmental factors will be discussed in this section.

a) Factors influencing corrosivity of the atmosphere

Environmental factors influencing the corrosivity of the atmosphere were reported as temperature, humidity, precipitation, sulfur-dioxide, sea-salt particles, wind direction, wind velocity, shining hours etc..[7),8),11)-17)] Among these, factors which greater influence the rate of steel corrosion are temperature, humidity, precipitation, sulfur-dioxide, and sea-salt particles.

Temperature: As for reaction velocity of the corrosion process, in general, increase in temperature will increase the reaction velocity. Consequently, corrosion rate of steel in high temperature atmospheres is higher than corrosion rate of steel in low temperature atmospheres. It is reported that each centigrade rise of temperature increase the rate of steel corrosion by 2.5 %.[7)]

Humidity: Humidity is a very important factor influencing the rate of steel corrosion. The rate of steel corrosion increases with increasing humidity. However, Vernon discovered that a critical humidity exists below which corrosion is negligible.[18)] Experimental values for the critical humidity are found to fall in general between 50 and 80 % for steel.[7),8),12)] Typical corrosion behavior of steel as a function of humidity of the atmosphere is shown in Fig. 2.4. Furthermore if the atmosphere is purified of substances such as sulfur dioxide concentration, sea-salt particles, and dust, critical value of humidity may reach some values such as 99 %.[13)] It was reported that when humidity is higher than critical value, the rate of corrosion will increase around 20 % by 1 % of the increment in humidity.[19)]

Precipitation: In general, precipitation is one of the most important factors influencing the rate of steel corrosion as it makes the steel surface wet. Moreover, precipitation can make the atmosphere more corrosive by increasing in humidity.

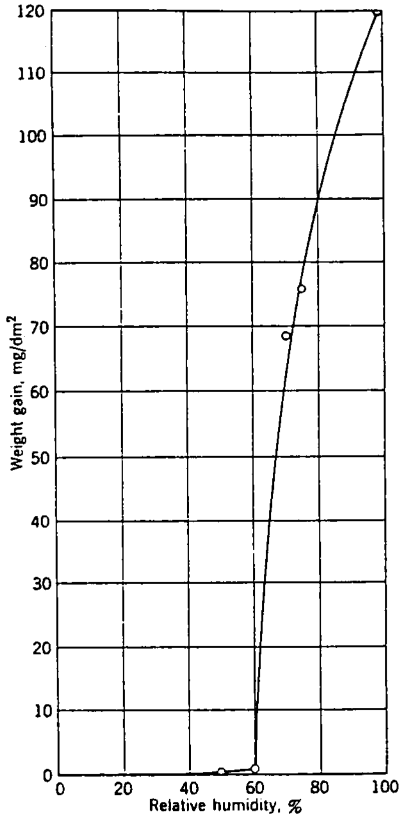

Fig. 2.4 Corrosion of iron in air containing 0.01 % SO_2, 55 days' exposure, showing critical humidity[18]

Sulfur-dioxide: The most important corrosive constituent of industrial atmospheres is sulfur-dioxide, which originates predominantly from the burning of coal, oil, and gasoline. Fig. 2.5 illustrates the influence of sulfur-dioxide on the rate of steel corrosion for different humidity.[20]

Sea-salt particles: Sea-salt particles are the most important corrosive constituent of especially marine atmospheres. The sea-salt particles in the atmosphere are produced on the sea surface, as a result of the direct interaction between the atmosphere and the ocean, and are carried over land by turbulence and wind. The rate of steel corrosion is high in the areas of high concentration of sea-salt particles. Fig. 2.6 shows the relationship between sea-salt particles and steel corrosion in the form of rating number.[21]

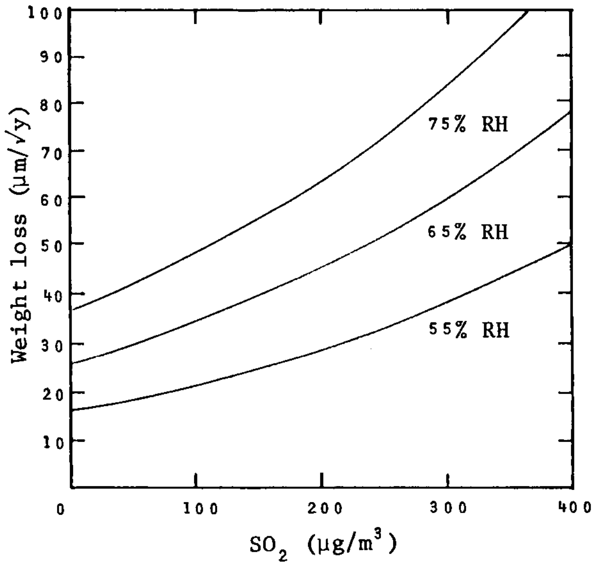

Fig. 2.5 Effect of sulfur dioxide concentration and humidity to the rate of corrosion of steel materials[20]

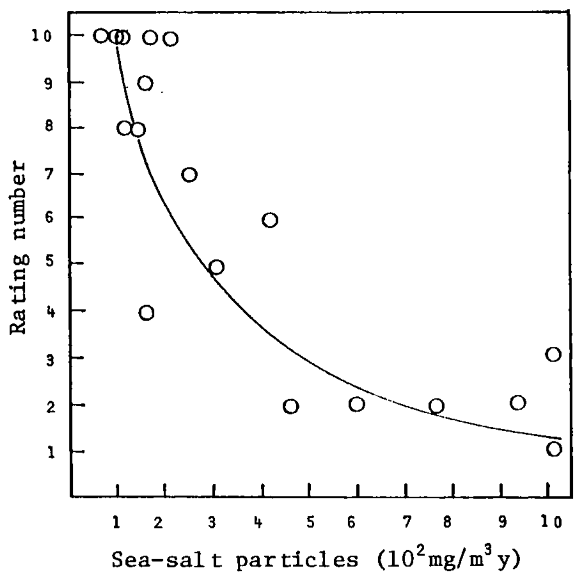

Fig. 2.6 Relation between adhered sea-salt fine particle weight and corrosion occurrence[21]

b) Estimation of sea-salt particles[22)-27)]

The sea-salt particles in the atmosphere are produced on the sea surface, as a result of the direct interaction between the atmosphere and the ocean. The particles produced on the sea surface are carried over land by turbulent diffusion and wind. On land, there is a large ground sink consisting of the dry fallout and the impaction by trees and other ground obstacles. The determination of this ground sink of particles is very important.

The number concentration of sea-salt particles in the atmosphere depends mainly on the meteorological condition such as wind speed, wind direction, and distance from the coast. In general, the number concentration of sea-salt particles can be expressed by the following equation.

$$u\frac{\partial \theta}{\partial x} = w\frac{\partial \theta}{\partial z} + D\frac{\partial^2 \theta}{\partial z^2} \qquad (2.4)$$

where u : wind velocity
D : vertical distribution factor of sea-salt particle
w : velocity of gravitational fall of the particles
x : axis in wind direction
z : vertical axis

If f is a downward flux of the particle, and equals zero for infinity distance in z direction: then

$$f = w\theta + D\frac{\partial \theta}{\partial z} \qquad (2.5)$$

From Eq. 2.5, the rate of dry fallout of sea-salt particle on the ground surface, F can be obtained when z is zero.

$$F = w\theta_0 + D\left(\frac{\partial \theta}{\partial z}\right)_{z=0} \qquad (2.6)$$

From this equation, Toba has introduced the term "impaction factor, λ " for the last term of the equation, and introduced the following equation.

$$\lambda u\theta_0 = D\left(\frac{\partial \theta}{\partial z}\right)_{z=0} \qquad (2.7)$$

The distribution of the particles inland is analytically expressed in the terms of dimensionless parameters, representing the number concentration (Θ), distance inland (x), height (z), and impaction factor (λ).

$$\Theta = \frac{\theta}{\theta_\infty} \;,\; \xi = \frac{w^2 x}{4Du} \;,\; \zeta = \frac{wz}{2D} \;,\; \gamma = \frac{\lambda u}{w} \qquad (2.8)$$

where Θ_{00} represents the number concentration at the ground surface closed to the coast.

Boundary conditions:

1 at coast $x = 0$, $\theta = \theta_\infty \, exp(-\frac{w}{D} z)$

2 at ground surface $z = 0$, $D \frac{\partial \theta}{\partial z} = \lambda u \theta$ (2.9)

3 at high level $z = \infty$, $\theta = 0$

From the above boundary conditions, the solution of the Eq. 2.4 when $\gamma \neq 0$ can be obtained as,

$$\Theta = \frac{1}{2} erfc(\sqrt{\xi} - \frac{\zeta}{2\sqrt{\xi}}) exp(-2\zeta) - \frac{1}{2}(1 + \frac{1}{\gamma}) \; erfc(\sqrt{\xi} + \frac{\zeta}{2\sqrt{\xi}})$$

$$+ (1 + \frac{1}{2\gamma}) exp[2\gamma \{\zeta + 2(1+\gamma)\xi\}] erfc\{(1+2\gamma)\sqrt{\xi} + \frac{\zeta}{2\sqrt{\xi}}\} \quad (2.10)$$

where
$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty exp(-u^2) d_u \quad (2.11)$$

The particle number concentration of sea-salt particles at ground surface can be expressed as

$$\Theta_o = (1 + \frac{1}{2\gamma}) exp\{4\gamma(1+\gamma)\xi\} erfc\{(1+2\gamma)\sqrt{\xi}\} - \frac{1}{2\gamma} erfc(\sqrt{\xi}) \quad (2.12)$$

The impaction factor in this equation is reported to fall between 0.01 and 0.03 according to the investigated results of Tanaka et al.

Steps of calculation

1) Estimating the number concentration of sea-salt particle at the sea surface, $\Theta_0(x=0)$

The factors that have a direct effect on the number concentration of sea-salt particles are wind speed (u), vertical distribution factor of sea-salt particles (D), and the velocity of gravitational fall of the particles (w). The last two terms do not have significant change compared with the first one, and can be considered as constants.

First of all, Reynolds number, the factor for describing weather condition is determined by using Eq. 2.13.

$$Re^* = u_* H / \nu \quad (2.13)$$

where
$$u_* = \gamma_{10} u_{10}$$

$$\gamma_{10}^2 = (1.00 + 0.07 \, u_{10}) \times 10^{-3}$$

$$H = 0.25 \, {u_{10}}^2 / g$$

here Re^* : Reynolds number

γ_{10} : Coefficient of friction of sea surface

u_{10} : Average wind speed at 10 m level

ν : Air viscosity

From this Reynolds number, the number concentration of sea-salt particles at the sea surface, Θ_0 can be obtained by using Fig. 2.7.[28]

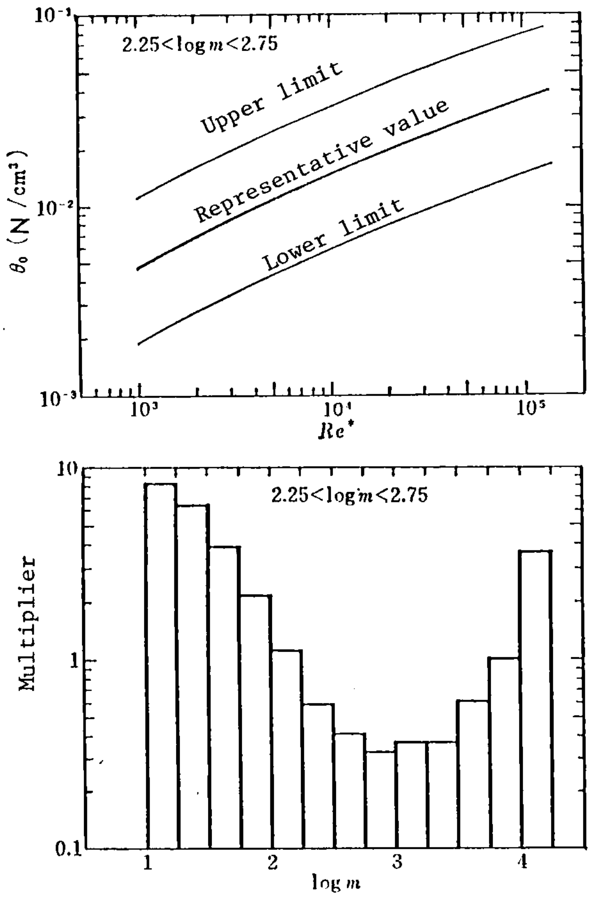

Fig. 2.7 Diagram for predicting sea-salt particles[28]

2) The relationship between the number concentration of sea-salt particles at 10 m level and at sea surface.

$$\log(\Theta_{10}/\Theta_0) = - m^{2/3} u \, 10^{-1} X(RH_{10}, \gamma_1 , Z) \quad (2.14)$$

where m is atomic weight of sea-salt particle (10^{-11}-10^{-9}g). RH_{10} is relative humidity. X is the function of RH_{10}, γ_1 , and z. In the case of RH_{10}= 80%, γ_1^2 = 1.6×10^{-3}, and z = 10 m, the value of X(RH_{10}, γ_1 ,10) is 5.0×10^{8}

$(g^{-2/3} cm/sec)$

From this equation, the ratio of the number concentration of sea-salt particle at sea surface to that at 10 m level, Θ_{10}/Θ_0 can be obtained.

3) The relationship between the number concentration of sea-salt particles at 10 m level and at ground surface.

case 1: at the coast where x=0
By using Eq.2.9, in which the term (w/D) can be obtained from Table 2.1,[27] the ratio of Θ/Θ_{10} can be obtained.

case 2: at any locations inland
By using Eq.2.10, the ratio of Θ/Θ_{10} can be obtained.

Table 2.1 Values of α(=w/D) and w used in the calculation[27]

log m	1.0	1.5	2.0	2.5	3.0	3.5	4.0
α (1/cm)	10^{-5}	10^{-5}	1.2×10^{-5}	1.6×10^{-5}	3.0×10^{-5}	4.0×10^{-5}	
w(D=10^5) cm/sec	1.0	1.0	1.2	1.6	3.0	4.0	

4) From 1) to 3) the number concentration of sea-salt particle at ground surface can be determined by

$$\Theta = (\Theta_{10}/\Theta_0)(\Theta/\Theta_{10})(\Theta_0) \qquad (2.15)$$

5) Finally, the amount of the sea-salt particles, X_5 in the equations for predicting corrosion at some certain exposure period can be determined by

$$X_5 \ (g/cm^2 \ y) = m \ (w + \lambda u \ ) \ \Theta[(365-X_6)/365] \ 3.1536\times10^7 \qquad (2.16)$$

where $(mw\Theta)$ is the salt sedimentation rate. $(m\lambda u\Theta)$ is the salt impaction rate. X_6 is the number of days in which the precipitation is over than 1 mm.

Estimation of sea-salt particles for each environment

1 Mountainous environment

In this case, the nearest distance from the sea as well as the mean wind speed in that direction are used for determining the amount of sea-salt particles. Fig. 2.8 shows the estimated results of sea-salt particle with the comparison of measured values. The impaction factor used in the calculation consists of 0.01, 0.015, 0.02, and 0.03. From these results,

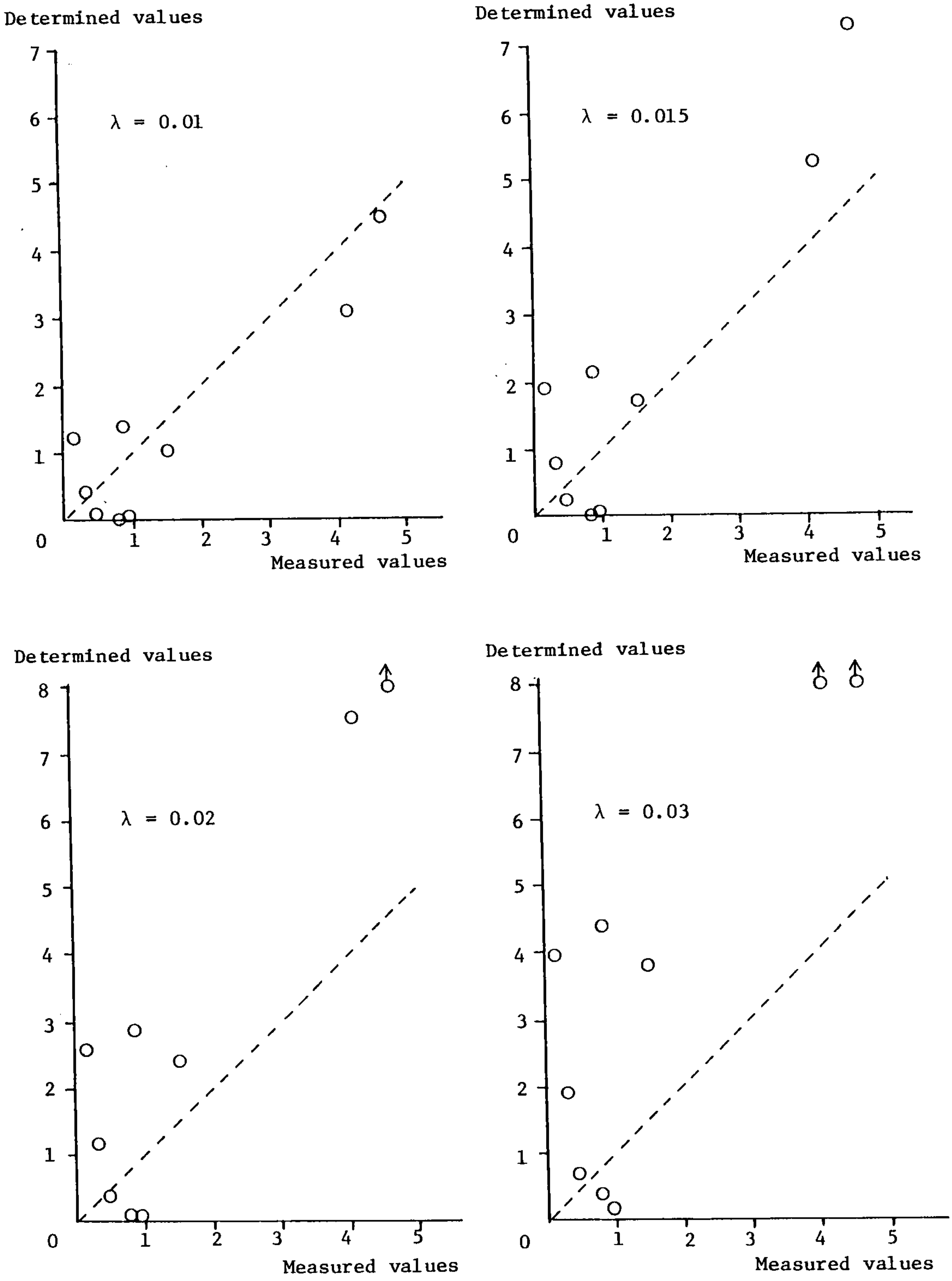

Fig. 2.8 Comparison between determined and measured sea-salt particles for mountainous environment ($10^{-4}g/cm^2y$)

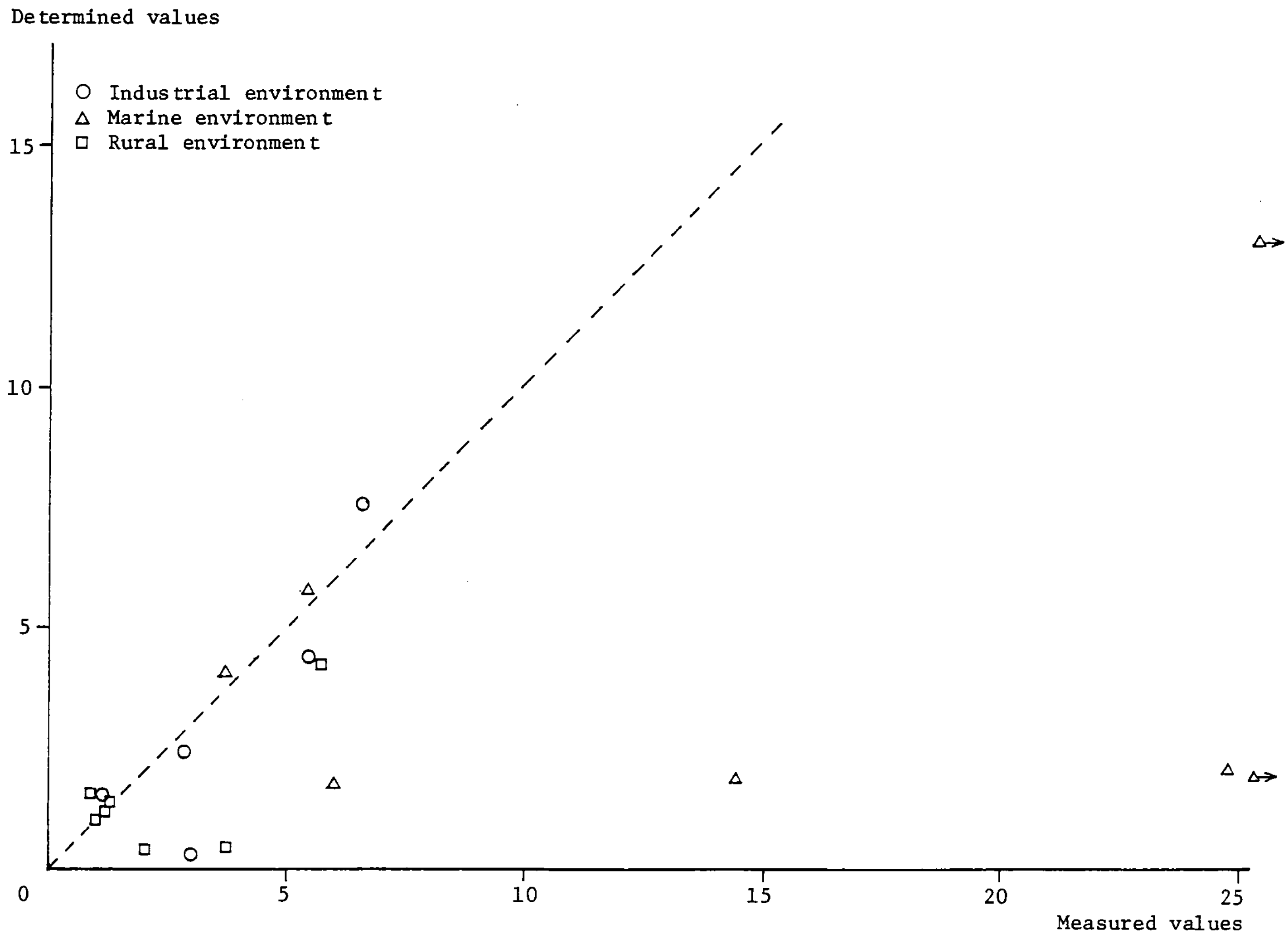

Fig. 2.9 Comparison between determined and measured sea-salt particles for rural, industrial and marine environment ($10^{-4}g/cm^2y$)

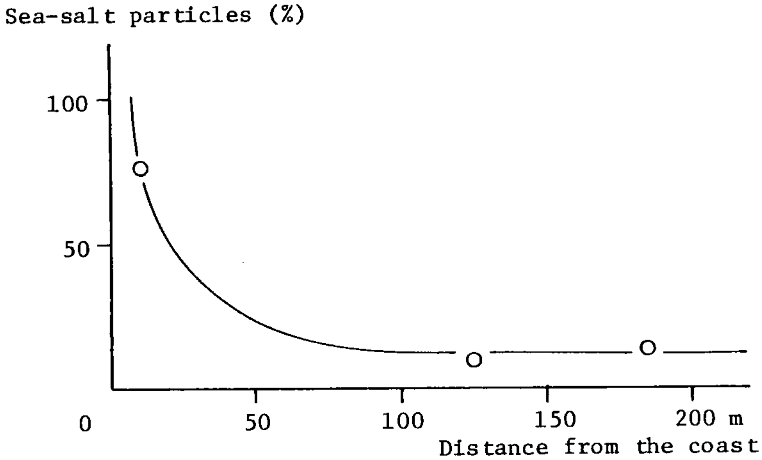

Fig. 2.10 Relation between the amount of sea-salt particles and the distance from the coast[29]

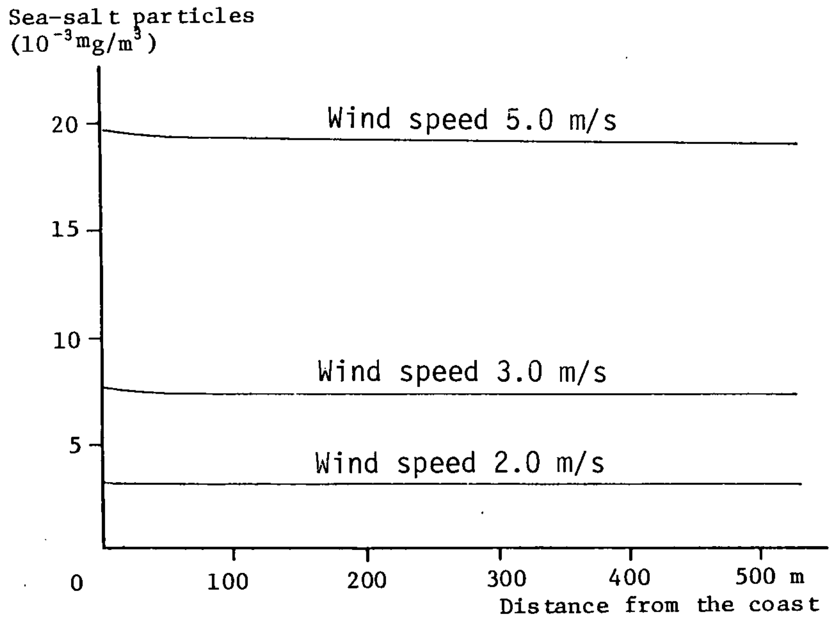

Fig. 2.11 Relation between determined sea-salt particles by the model of Toba and Tanaka and the distance from the coast

estimated values accord well with the measured values for the impaction factor 0.01.

2 Rural, industrial, and marine environment

In this case, wind directions are divided into 16 directions. From these 16 directions, the directions of wind from sea are selected, and the average wind speed as well as the distance inland in these wind directions are used for estimating sea-salt particles. The impaction factor selected in the calculation is 0.01. Results of the estimated sea-salt particles with the comparison of measured values are shown in Fig. 2.9.

From these results, the estimated results of sea-salt particle for rural and industrial environment accord well with the measured values. But this value is underestimated for marine environment. This can be explained by using Fig. 2.10[29] and Fig. 2.11. Fig. 2.10 shows the relationship between the distance from the coast and the amount of sea-salt particle (in percent). It is clearly seen that the amount of sea-salt particles increases rapidly when the distance from the coast is less than 100 m while the predicted result of sea-salt particles by the model of Toba and Tanaka does not increase significantly, especially for low wind speed. The rapid increasing of sea-salt particles near the coast is considered to be caused by sea spray.

2.4 PREDICTION OF CORROSION OF BARE STEEL

a) Long-term corrosion of bare steel

Horikawa et al[30] have studied the long-term corrosion behavior of bare steel, and introduced the equation for predicting long-term corrosion of bare steel as follows:

$$Y = A\ t^{B} \exp(C/t) \qquad (2.17)$$

where Y represents predicting long-term corrosion of bare steel, t represents exposure time. A, B, and C are constants.

This equation can represent the corrosion behavior of bare steel when exposure time is far from zero. When exposure time is zero or close to zero, this equation cannot represent the corrosion behavior of bare steel, because this equation cannot give accurate proof that corrosion must be zero when exposure time is zero. Therefore, the other equation, which gives a good representation of corrosion behavior is introduced. This equation is as follows:

$$Y = k\ t^{m} \qquad (2.18)$$

where Y represents predicting long-term corrosion of bare steel, t represents exposure time. k and m are constants. This equation is readily convertible to a linear expression of the form

$$\ln Y = k' + m \ln t \tag{2.19}$$

where k' represents lnk.

The parameters k and m play a significant role in the characteristics of atmospheric corrosion and provide an important role to understand its behavior. If these parameters are known, Eq. 2.19 (or Eq. 2.18) can be used to predict the corrosion depth of bare steel at any exposure times.

In order to determine the parameters k and m, the results of a steel exposure test for the interested area should be obtained. This test should be placed at different exposure periods, for instance, 1,2,3,4, and 5 year-exposure periods. The data of corrosion depth from the exposure test are applied directly to Eq. 2.19, and then by the least square method, the parameters k and m can be determined.

For bare steel exposed to rain, based on the results of the steel exposure test conducted by the Hanshin Expressway Public Corporation,[31] parameters k and m for 15 places in Japan are obtained. Results of the parameter estimation are shown in Table 2.2A. Table 2.2B shows the results of estimated parameters in the equation for predicting long-term corrosion of Horikawa.

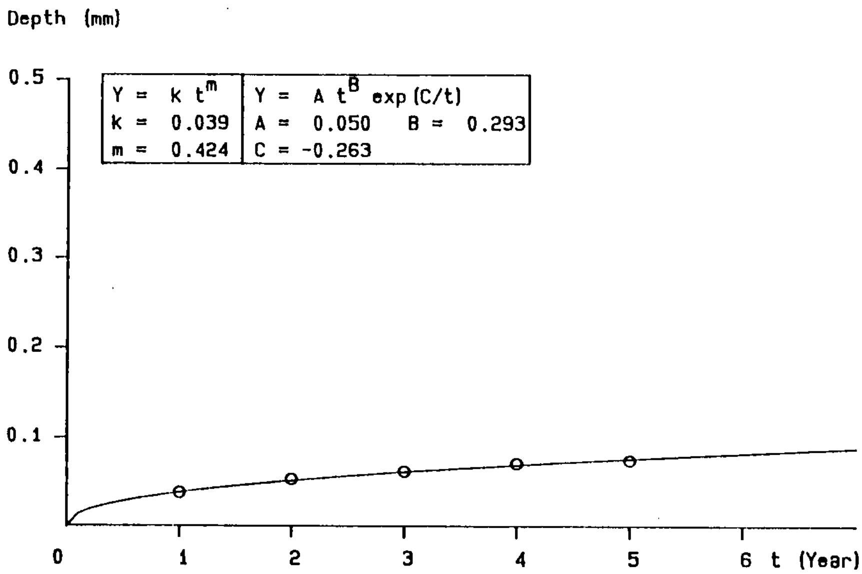

Fig. 2.12 Long-term corrosion of bare steel exposed to rain
Otaru

Table 2.2A Estimated parameters in the equation for predicting long-term corrosion for members exposed to rain ($Y = k\ t^m$)

Location	k	m
Otaru	0.039	0.424
Sendai	0.042	0.363
Niigata	0.055	0.415
Nagano	0.026	0.363
Nagoya	0.068	0.314
Shimizu	0.046	0.836
Tokyo	0.059	0.324
Kawasaki	0.144	0.613
Matsue	0.035	0.542
Amagasaki	0.088	0.592
Wakayama	0.062	0.318
Shionomisaki	0.055	0.663
Miyasaki	0.037	0.500
Matsuyama	0.047	0.311
Ashizurimisaki	0.086	1.056

Table 2.2B Estimated parameters in the equation for predicting long-term corrosion for members exposed to rain ($Y = A\ t^B \exp(C/t)$)

Location	A	B	C
Otaru	0.050	0.293	-0.263
Sendai	0.036	0.455	0.184
Niigata	0.046	0.509	0.189
Nagano	0.031	0.270	-0.188
Nagoya	0.101	0.099	-0.432
Shimizu	0.063	0.659	-0.354
Tokyo	0.047	0.447	0.246
Kawasaki	0.079	0.931	0.640
Matsue	0.041	0.429	-0.227
Amagasaki	0.124	0.407	-0.370
Wakayama	0.086	0.138	-0.361
Shionomisaki	0.099	0.349	-0.631
Miyasaki	0.138	0.197	-1.398
Matsuyama	0.111	0.148	-0.920
Ashizurimisaki	0.027	1.665	1.223

Table 2.3A Estimated parameters in the equation for predicting long-term corrosion for members underneath bridges ($Y = k\ t^m$)

Environment	No	Bridge Name	Location	k	m
Rural (3)	9	Shinjoe	Omiya	0.018	0.636
	32	Hirokawa	Ozu	0.017	0.592
	41	Minamiodan 4-2	Dobokukenkyujo	0.012	0.638
Mountainous (11)	3	Takihue	Chitose	0.016	0.695
	6	Daido	Higashine	0.010	0.594
	8	Ominezawa	Shinji, Tone	0.008	0.528
	15	Joro	Tsugawa	0.012	0.462
	16	Hamaguri	Furukawa	0.006	1.164
	21	Yamagami	Otsu	0.015	0.613
	26	Miyoshi	Miyoshi	0.014	0.493
	29	Keido	Kagawa-Tokushima	0.010	0.442
	34	Nishinotani	Kashiwabara, Kuju	0.010	0.649
	39	Ishihira	Okinawa	0.025	0.733
	40	Kenjo	Naha	0.021	0.631
Industrial (7)	4	Hahakoi	Muroran	0.023	0.674
	10	Ebigawa	Funabashi	0.033	0.466
	14	Senpogawa	Takaoka	0.018	0.842
	19	Yokkaichi	Yokkaichi	0.018	0.770
	23	Nishiyodogawa	Osaka	0.015	0.773
	28	Shinkasumi	Kurashiki	0.012	0.661
	36	Chuo	Kitakyushu	0.011	0.786
Marine (11)	1	Ishikari	Ishikari	0.041	0.805
	5	Takagi	Matsushima	0.017	0.891
	13	Yoneyama	Kashiwazaki	0.067	1.197
	17	Shinryoku	Ohama	0.087	1.085
	20	Arita	Arita By-pass	0.015	1.028
	24	Hamamura	Hoki, Kedaka	0.124	1.195
	25	Gonokawa	Gotsu	0.019	0.724
	31	Yasudagawa	Yasuda	0.077	1.203
	33	Kizaki	Miyazaki	0.041	0.825
	37	Shioya	Shioya-wan	0.365	0.614
	38	Setoke	Nago	0.058	0.966
City (9)	2	Toyohira	Sapporo	0.008	0.799
	7	Natori	Sendai	0.017	0.826
	11	Owariya	Yokohama	0.015	0.475
	12	Shinkumihakamasen	Nagaoka	0.041	0.624
	18	Kozoku	Nagoya	0.015	0.735
	22	Gojo	Kyoto	0.012	0.512
	27	Izumida	Okayama	0.014	0.637
	30	Onogawa	Matsuyama	0.015	0.594
	35	Jurogawa	Fukuoka	0.035	0.420

Table 2.3B Estimated parameters in the equation for predicting long-term corrosion for members underneath bridges ($Y = A\ t^B \exp(C/t)$)

Environment	No	Bridge Name	Location	A	B	C
Rural (3)	9	Shinjoe	Omiya	0.019	0.593	-0.071
	32	Hirokawa	Ozu	0.013	0.550	-0.069
	41	Minamiodan 4-2	Dobokukenkyujo	0.013	0.598	-0.067
Mountainous (11)	3	Takihue	Chitose	0.018	0.654	-0.068
	6	Daido	Higashine	0.011	0.553	-0.067
	8	Ominezawa	Shinji, Tone	0.009	0.486	-0.069
	15	Joro	Tsugawa	0.013	0.416	-0.075
	16	Hamaguri	Furukawa	0.016	0.629	-0.070
	21	Yamagami	Otsu	0.016	0.570	-0.071
	26	Miyoshi	Miyoshi	0.015	0.447	-0.076
	29	Keido	Kagawa-Tokushima	0.010	0.397	-0.074
	34	Nishinotani	Kashiwabara, Kuju	0.011	0.610	-0.065
	39	Ishihira	Okinawa	0.027	0.690	-0.070
	40	Kenjo	Naha	0.023	0.586	-0.073
Industrial (7)	4	Hahakoi	Muroran	0.024	0.630	-0.072
	10	Ebigawa	Funabashi	0.036	0.414	-0.086
	14	Senpogawa	Takaoka	0.020	0.804	-0.062
	19	Yokkaichi	Yokkaichi	0.019	0.730	-0.065
	23	Nishiyodogawa	Osaka	0.016	0.735	-0.063
	28	Shinkasumi	Kurashiki	0.013	0.621	-0.066
	36	Chuo	Kitakyushu	0.011	0.750	-0.059
Marine (11)	1	Ishikari	Ishikari	0.044	0.761	-0.072
	5	Takagi	Matsushima	0.018	0.856	-0.058
	13	Yoneyama	Kashiwazaki	0.047	1.411	0.354
	17	Shinryoku	Ohama	0.468	0.063	-1.684
	20	Arita	Arita By-pass	0.035	0.515	-0.845
	24	Hamamura	Hoki, Kedaka	0.780	0.079	-1.839
	25	Gonokawa	Gotsu	0.020	0.683	-0.068
	31	Yasudagawa	Yasuda	1.862	0.730	-3.185
	33	Kizaki	Miyazaki	0.044	0.782	-0.071
	37	Shioya	Shioya-wan	0.407	0.551	-0.104
	38	Setoke	Nago	0.062	0.925	-0.068
City (9)	2	Toyohira	Sapporo	0.009	0.765	-0.056
	7	Natori	Sendai	0.018	0.788	-0.062
	11	Owariya	Yokohama	0.016	0.428	-0.077
	12	Shinkumihakamasen	Nagaoka	0.044	0.575	-0.081
	18	Kozoku	Nagoya	0.016	0.696	-0.065
	22	Gojo	Kyoto	0.013	0.467	-0.073
	27	Izumida	Okayama	0.015	0.596	-0.069
	30	Onogawa	Matsuyama	0.016	0.550	-0.072
	35	Jurogawa	Fukuoka	0.038	0.366	-0.089

In the case of member underneath bridges, the parameter estimation is based on the results of the steel exposure test underneath bridges conducted by the Public Works Research Institute.[32] Results of the parameter estimation are shown in Table 2.3A. Table 2.3B shows the results of estimated parameters in the equation for predicting long-term corrosion of Horikawa. Fig. 2.12 shows one example of the results of long-term corrosion of bare steel exposed to rain for Otaru. Other results of long-term corrosion of bare steel are shown in the appendix.

b) Corrosion of bare steel at certain exposure times

When there is no data of corrosion depth from the steel exposure test for the interested area, the parameters k and m, cannot be directly determined. In this case, instead of data from the steel exposure test, it is necessary to prepare the regression equations for predicting corrosion at certain exposure times, i.e. at 1,2,3,4, and 5 year-exposure times, as a function of environmental factors. From these regression equations, corrosion depths for certain exposure times can be predicted when the data of environmental factors for the interested area are obtained. These expected corrosion depths are applied to Eq. 2.19 in order to identify the parameters k and m. These regression equations are divided into two groups. The first one is for the members exposed to rain, and the other one is for the members underneath bridges.

For the members exposed to rain, the data of environmental factors and corrosion depth from the steel exposure test conducted by the Hanshin Expressway Public Corporation that are shown in Table 2.4 are used. These data are applied to the SPSS Statistical Package, and by the multiple linear regression analysis, regression equations for predicting corrosion at 1,2,3,4, and 5 year-exposure times are obtained. These regression equations are as follows:

$$Y_1 = 551.7 + 53.2X_1 - 15.4X_2 - 0.111X_3 + 33.9X_4 + 4.46X_5 \qquad \gamma = 0.65 \qquad (2.20)$$

$$Y_2 = 878.3 + 75.1X_1 - 26.9X_2 + 0.021X_3 + 47.8X_4 + 5.99X_5 \qquad \gamma = 0.68 \qquad (2.21)$$

$$Y_3 = 2001 + 101.3X_1 - 49.1X_2 + 0.120X_3 + 57.3X_4 + 6.83X_5 \qquad \gamma = 0.62 \qquad (2.22)$$

$$Y_4 = 5289 + 118.3X_1 - 96.1X_2 + 0.333X_3 + 39.4X_4 + 7.29X_5 \qquad \gamma = 0.59 \qquad (2.23)$$

$$Y_5 = 5793 + 131.5X_1 - 111.4X_2 + 0.503X_3 + 55.9X_4 + 7.57X_5 \qquad \gamma = 0.58 \qquad (2.24)$$

Condition (a): $Y_5 > Y_4 > Y_3 > Y_2 > Y_1 > 0$

in which X_1 is temperature (°C). X_2 is humidity (%). X_3 is precipitation (mm/year). X_4 is sulfur dioxide concentration (10^{-3}ppm). X_5 is sea-salt particles (10^{-4}g/cm^{2}year). Y is predicting corrosion depth (10^{-4}mm), the subscript of Y expresses the time of exposure in a year.

Table 2.4 Data of environmental factors and corrosion depths for members exposed to rain

Location	X_1 T °C	X_2 RH %	X_3 Pre. mm/y	X_4 SO_2 10^{-3}ppm	X_5 NaCl $10^{-4}g/cm^2y$	Y_1	Y_2	Y_3	Y_4	Y_5
						Corro. Depth 10^{-4}mm				
Otaru	8.4	71	1158	15.3	7.66	382	533	622	711	747
Sendai	11.9	73	1219	12.6	1.55	427	533	622	702	764
Niigata	13.1	75	1822	10.2	12.50	560	711	871	1000	1070
Nagano	11.4	74	987	17.9	0.38	258	338	391	444	453
Nagoya	14.9	71	1575	16.4	0.37	658	880	960	1070	1080
Shimizu	16.0	69	2361	14.9	2.44	444	844	1150	1446	1710
Tokyo	15.3	66	1460	18.2	5.34	596	729	809	933	1006
Kawasaki	15.3	70	1427	21.2	22.70	1510	2040	2810	3388	4000
Matsue	14.4	78	1957	12.4	18.40	347	533	640	738	844
Amagasaki	16.3	69	1277	16.8	8.86	860	1360	1740	1990	2220
Wakayama	16.0	70	1454	12.1	21.20	604	773	907	978	978
Shionomisaki	16.9	72	2766	10.7	82.30	524	951	1110	1410	1530
Miyazaki	16.9	77	2490	11.4	5.52	338	613	684	711	782
Matsuyama	15.6	71	1337	16.9	5.99	444	631	702	720	729
Ashizurimisaki	17.8	70	2473	9.9	26.70	933	1560	2520	4070	4810

In these equations, humidity does not show the promotion of corrosion deterioration. This behavior also has been reported by the former researches.[11),30)] This may be because the data of humidity used in this calculation is not so high (ranging from 66% to 78% with the average at 71%), and is still lower than the critical value, in which humidity will not promote corrosion. Therefore, these regression equations are suitable for areas in which humidity is not so high and condition (a) is still true. For areas of high humidity, difference regression equations should be determined.

For members underneath bridges, the data of environmental factors and corrosion depth from the steel exposure test underneath bridges conducted by the Public Work Research Institute are used. These data are shown in Table 2.5. By the multiple linear regression analysis, regression equations for predicting corrosion at 1, 2, and 3 year-exposure times are obtained. These regression equations are as follows:

$$Y_1= 47.29+ 1.83X_1- 1.47X_2+0.07X_3-0.53X_4+27.21X_5 \qquad \gamma = 0.92 \qquad (2.25)$$

$$Y_2=-416.63+ 5.06X_1+ 4.72X_2+0.09X_3-1.10X_4+51.16X_5 \qquad \gamma = 0.93 \qquad (2.26)$$

$$Y_3=-973.27+ 8.54X_1+11.70X_2+0.11X_3-1.59X_4+73.64X_5 \qquad \gamma = 0.92 \qquad (2.27)$$

Condition (b): $Y_3>Y_2>Y_1>0$

In these equations, sulfur-dioxide does not show the promotion of corrosion deterioration. The same behavior also has been reported by the Public Works

Table 2.5 Data of environmental factors and corrosion depths for members underneath bridges

Environment	No	X_1 T °C	X_2 RH %	X_3 Pre. mm/y	X_4 SO_2 10^{-3}ppm	X_5 NaCl $10^{-4}g/cm^2y$	Y_1 Corro. Depth 10^{-4}mm	Y_2	Y_3
Rural (3)	9	14.1	69	1207	13.50	2.88	176	275	354
	32	-	-	-	-	1.13	120	182	230
	41	-	-	-	-	0.66	122	191	246
Mountainous (11)	3	6.3	79	1631	8.13	1.53	164	267	352
	6	11.2	76	1163	-	0.47	100	152	192
	8	13.8	67	1155	-	0.33	84	122	150
	15	-	-	-	-	0.88	118	164	196
	16	10.3	79	1832	-	0.95	64	-	230
	21	14.1	77	1741	-	0.80	150	231	294
	26	-	-	-	-	1.57	142	201	244
	29	15.2	74	1199	-	0.18	96	131	156
	34	15.6	74	1708	-	0.88	100	158	204
	39	22.4	77	2128	3.17	4.67	254	424	568
	40	22.4	77	2128	7.00	4.12	212	330	424
Industrial (7)	4	8.9	75	1303	9.36	5.40	228	366	478
	10	15.3	66	1460	16.44	6.75	332	462	554
	14	13.5	79	2346	11.64	3.03	184	331	464
	19	15.0	73	1708	10.27	2.99	176	302	410
	23	16.2	67	1400	18.64	5.55	154	264	360
	28	14.6	75	1223	16.82	1.50	118	188	244
	36	15.5	74	1718	10.45	1.24	108	187	256
Marine (11)	1	8.0	73	1158	4.17	14.45	408	717	988
	5	11.9	73	1219	2.30	6.10	166	309	442
	13	13.1	77	2948	-	24.86	672	-	2502
	17	15.5	74	4118	-	10.80	868	-	2858
	20	16.0	70	1454	-	5.69	152	-	470
	24	14.3	76	2018	-	62.49	1240	-	4608
	25	15.1	73	1740	6.50	3.80	186	309	412
	31	16.4	74	2524	-	16.86	770	-	2888
	33	16.9	77	2490	-	12.96	408	727	1010
	37	22.4	77	2128	-	41.14	3652	5634	7166
	38	22.4	77	2128	4.00	13.21	582	1143	1682
City (9)	2	8.0	73	1158	13.09	1.06	84	147	202
	7	11.9	73	1219	9.55	2.08	172	306	426
	11	15.1	71	1596	13.00	0.99	146	204	246
	12	-	-	-	-	6.53	408	633	810
	18	14.9	71	1575	11.55	1.13	148	248	332
	22	15.2	70	1669	14.36	1.46	122	175	214
	27	14.6	75	1223	17.55	3.83	140	219	282
	30	15.6	71	1337	14.82	1.31	150	228	288
	35	16.0	72	1690	8.00	5.80	348	469	552

Research Institute.[44] This may be because the number of data used in the analysis is too small and the data of corrosion deterioration in the areas of low concentration of sulfur-dioxide are high due to the other factors that may effect the rate of corrosion deterioration. Therefore the sense that sulfur-dioxide should promote corrosion deterioration is not observed in this analysis. For the real behavior of sulfur-dioxide, the future investigation is required. Table 2.6 shows the single-correlation coefficients between corrosion depths and environmental factors for both members exposed to rain and members underneath bridges.

From these regression equations, when the data of environmental factors for interested area are obtained, corrosion depths for some certain exposure times can be predicted. Applying the results to the Eq. 2.19, and by the least square method the parameters k and m in the equation for predicting long-term corrosion can be determined.

Table 2.6 Single-correlation coefficients between environmental factors and corrosion depths at some certain exposure times

		X_1	X_2	X_3	X_4	X_5
Based on steel exposure test exposed to rain	Y_1	0.366	-0.447	-0.026	0.372	0.192
	Y_2	0.499	-0.428	0.177	0.248	0.299
	Y_3	0.482	-0.397	0.215	0.174	0.277
	Y_4	0.484	-0.370	0.298	0.043	0.297
	Y_5	0.475	-0.354	0.305	0.043	0.286
Based on steel exposure test underneath bridges	Y_1	0.305	0.115	0.299	-0.491	0.885
	Y_2	0.299	0.203	0.314	-0.533	0.889
	Y_3	0.294	0.239	0.317	-0.541	0.874

2.5 METHODS FOR PROTECTION OF STEEL MATERIALS AGAINST CORROSION

Since steel is not stable in nature, it trends to change to a stable form of oxide whenever it is exposed to atmosphere, water, or soil. Consequently in order to refrain from this behavior, proper protecting methods of steel against corrosion are required. These methods for protecting steel (exposed to atmospheres) against corrosion can be classified into five groups as follows:[33]

a) Coatings (organic and inorganic)
b) Metallic coatings
c) Cathodic protection
d) Alloying
e) Control of environments

a) Coatings

Normally protective coatings applied to steel for protection against atmospheric corrosion are paints. Paints are mixtures of many raw materials. Some components can have a very significant effect when used in proportions as low as 0.01 per cent of the total, whereas others can be varied to some extent without having too drastic an effect. Basically, paint consists of three major components as follows:[34)-36)]

- Binder (sometimes called resin, vehicle, or polymer)
- Pigment and extender
- Solvent

Of these, only the first two form the paint film which protects and decorates the structures. The solvent is present to give good application properties and is really an expensive waste material. More details will be discussed later in chapter 3.

b) Metallic coatings

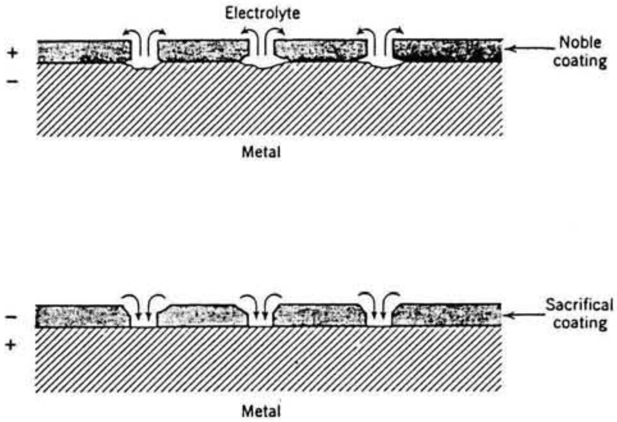

Fig. 2.13 Sketch of current flow at defects in noble and sacrificial coatings[8)]

Table 2.7 Corrosion rate of mild steel and galvanized steel in atmospheres (10^{-3} mm/y)[38)]

Environment	Japan			England		
	Place	Mild steel 0.06 % C	Galvanized Steel 0.15 % Al	Place	Mild steel 0.2 % C	Galvanized Steel
Marine	Oiso	40.5	1.28	Calshot	86.4	3.56
City	Tokyo	61.2	1.52	Woolwich	101.6	3.81
Industrial	Kawasaki	64.8	2.01	Motherwells	91.4	4.32
Heavy Indus.	Industry	116.0	7.78	Sheffield	139.7	13.20
Rural	Aizu	49.5	2.74	Llanwrtydwells	66.0	2.79

Metallic coatings are widely used in practice as an effective means for the corrosion control of metallic materials. Metallic coatings perform a long service life. It was reported that the service life of zinc coating, 400-700 g/m^2, may sometime be over 60 years.[37] Metallic coatings can be divided into two classes, which is noble and sacrificial. For noble coatings (e.g. nickel, lead, silver, copper, or chromium) on steel, the direction of current accelerates attack of the base metal. But for sacrificial coatings (e.g. zinc, cadmium, or aluminum) on steel, the direction of current through the electrolyte is from coating to base metal; as a result of this, the base metal is cathodically protected (Fig. 2.13). So long as adequate current flows and the coating remains in electrical contact, corrosion of base metal does not occur.

The most common metallic coating used to protect steel in atmospheres is zinc coating. The main advantages of zinc coating are its long service life and its economic. Corrosion rate of galvanized steel plate is very low compare with mild steel (Table 2.7).[38] There are also the others advantages as follows:[39]

- Good adhesive property
- Good surface finishing
- High reliability
- Can reduce time of construction

c) Cathodic protection

In general, cathodic protection is useful for corrosion control of only submerged or buried metals that are exposed to aqueous environments or to media such as soils containing liquid electrolyte as the conducting component.[40),41] Thus, it is frequently stated that the technique cannot be employed to prevent corrosion above the water line, because the impressed current cannot reach metal areas that are out of contact with the electrolyte.[8] However, Doufu[42] stated that cathodic protection can be employed with the combination of coating. The key to applying impressed current cathodic protection in atmospheric environments is to use a solid ionic conductor as an alternative to a liquid electrolyte, and the type of paint characterized by ionic conduction is required. Doufu found that the introduction of a solid electrolyte into the paint can solve this problem. The concept can be illustrated by Fig. 2.14.

The overall coating system is constructed by coating the metallic surface to be protected with the solid electrolyte containing coating (CK coating), then with an electronically conducting coating that acts as the anode. The metal is then cathodically polarized using an external dc source. To assist control of the cathodic potential, a graphite reference electrode is embedded in the CK coating.

By this method, steel materials can be protected against corrosion in atmospheres with high efficiency. Table 2.8 illustrates corrosion rates and

Table 2.8 Summary of corrosion rates (by weight loss) and protection efficiency under cathodic protection by means of CK coating: 40° C, moist atmosphere, test duration 7 days[42]

Condition	16 Mn steel		Mild steel	
	Corrosion rate (mm/year)	Protection efficiency (%)	Corrosion rate (mm/year)	Protection efficiency (%)
Control specimen without coating and cathodic protection	0.636	0	0.221	0
Coated specimen without cathodic protection	0.066-0.134	73.6-87.7	0.063-0.088	60.0-71.4
Coated specimen under cathodic protection*				
-200 mV	0.027-0.073	88.5-95.8	...	...
-350 mV	0.0078-0.0095	98.5-98.8	...	...
-500 mV	0.0008-0.0045	99.3-99.9	...	...
-700 mV	0.002-0.014	97.8-99.7	...	...
-850 mV	0.016-0.036	93.3-96.9	0.0057-0.0060	97.3-97.4

* Voltages relative to graphite electrode

Table 2.9 Effect of low-alloy components on atmospheric corrosion of commercial steel sheet (Eight-year exposure)[8]

Steel	Composition (%)				Loss of thickness	
	C	P	Cu	Other	(mm)	(mils)
	Industrial atmosphere (Kearney, N.J.)					
Carbon	0.2	0.02	0.03		0.20	8.0
Copper-bearing	0.2	0.02	0.3		0.11	4.4
Low-chromium	0.09	0.2	0.4	1 Cr	0.048	1.9
Low-nickel	0.2	0.1	0.7	1.5 Ni	0.051	2.0
	Temperate marine atmosphere* (Kurb Beach, N.C.)					
Carbon	0.2	0.02	0.03		0.24	9.5
Copper-bearing	0.2	0.01	0.2		0.15	5.8
Low-chromium	0.1	0.14	0.4	1 Cr	0.069	2.7
Low-nickel	0.1	0.1	0.7	1.5 Ni	0.076	3.0
	Tropical marine atmosphere (Panama Canal zone)					
Carbon	0.25	0.08	0.02		0.52	20.4
Copper-bearing	0.2	0.004	0.24		0.45	17.6
Low-chromium	0.07	0.008	0.1	3.2 Cr	0.23	9.1
Low-nickel	0.2	0.04	0.6	2.1 Ni	0.19	7.5

* 7.5-year exposure

protection efficiency under cathodic protection.[42)]

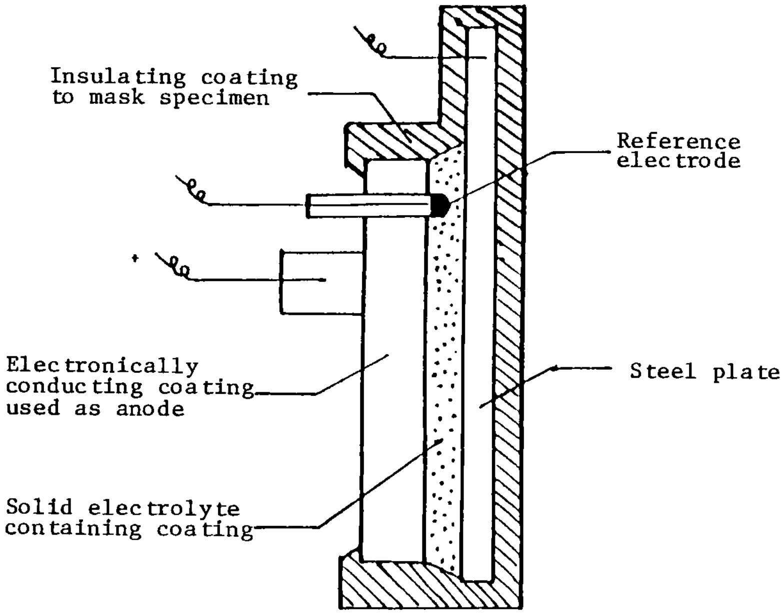

Fig. 2.14 Schematic diagram of electrode assembly used for experiments[42)]

d) Alloying

Alloying is an effective means for improving the resistance of metals to attack by corrosive environments. When alloyed with steel in small concentrations, copper, phosphorus, nickel, and chromium are particularly effective in reducing atmospheric corrosion. Table 2.9 shows the effect of low-alloy components on atmospheric corrosion of steel.[8)]

The usefulness of low-alloy steels to effectively resist atmospheric corrosion through formation of protective rust films has resulted in the development of so-call weathering steels. There are employed for construction of buildings or bridges without the necessity of painting, thereby saving appreciable in maintenance costs over the life of the structure.

e) Control of environment

The other method for protection of steel materials against corrosion in atmospheric environments is to control the environment. The methods of controlling humidity and removing impurities can be applied. As mentioned before, a critical humidity exists below which corrosion is negligible. Therefore, if humidity is controlled at lower than the critical value, corrosion protection will be effective.

Removing atmospheric impurities such as dust, sulfur-dioxide, and sea-salt particles is also effective for the protection of steel materials against corrosion. It was reported that if the atmosphere is thoroughly purified, there is no corrosion even at 99 % RH.[43]

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3 EVALUATION OF SERVICE LIFE OF PAINT[1)-10)]

3.1 INTRODUCTION

The most common method for protecting steel materials against corrosion in atmosphere is to apply paints to the steel surface. Paints are mixtures of many raw materials, any one paint can contain from ten to twenty components. Some components can have a very significant effect when used in proportions as low as 0.01 per cent of the total, whereas others can be varied to some extent without having too drastic an effect. Basically, paint consists of the three major components of binder, pigment and extender, and solvent.[11)-13)] Of these, only the first two form the paint film which protects and decorates the structures. The solvent is present to give good application properties and is really an expensive waste material.

Binders are predominant in determining the characteristics of paints. The function of the binder or resin is to give a permanent continuous film which is responsible for adhesion to the surface, resistance to climatic conditions, and mechanical and chemical resistance.

Pigments are any substances used as coloring. Pigmentation of the polymer give the final paint film. Pigments can be divided into the following types:

- Anti-corrosive pigment: to prevent corrosion of metals by chemical or electrochemical means.
- Barrier pigments: to increase impermeability of the paint film.
- Coloring pigments: to give permanent coloring.
- Extenders: to help give the film properties that are required.

Solvents used in paint perform no really useful function other than enabling an even film of paint to be applied with minimum difficulty. Many paint-property parameters can be varied by changing the solvent. The most important of which are viscosity and drying time. These features, along with the odor of the solvent, are of great importance to the paint user.

3.2 FACTORS INFLUENCING SERVICE LIFE OF PAINT

There are many factors influencing the rate of paint film deterioration. For structural steelwork exposed to the atmosphere, however, main factors that influence the rate of paint film deterioration are atmospheric environments, structural details, types of paint, thickness of paint film, and steel surface preparation.[12)-19)]

a) Atmospheric Environments

Service life of paint is greatly different according to atmospheric environments. The main factors that affect the rate of paint film deterioration are environmental factors such as temperature, humidity, precipitation, sulfur dioxide concentration, and sea-salt particles; which are widely different in each atmospheric environment. Past investigation found that proper service life of paints are 6.9 years for rural environments, 7.8 years for mountainous environments, 6.0 years for industrial environments, and 3.9 years for marine environments.[20)-21)] Table 3.1 shows service life of paints according to atmospheric environments for alkyd resins and chlorinated rubber.[16)]

Table 3.1 Proper service life of paint (year)[16)]

Environment	Binder	
	Alkyd resins	Chlorinated rubber
Mountainous	6-7	7-8
Rural	6-7	7-8
City	5-6	7-8
Marine	3-4	3-4

b) Structural details

The effectiveness of paints also depends on structural details. For structural steel bridges, service life of paint depends on the parts of the bridge to which paint is applied. One considerable reason is the state of moisture at the surface of steel. For instance, surface underneath bridges will retain moisture longer than those periodically exposed to the sun. This is also the case when the surface is sheltered by trees or foliage. In general, service life of paints at the edge of the girder, bolt-head, gusset plate, the bottom surface of the lower flange, and the bottom surface of the box girder are usually shorter than other parts.[22)]

c) Types of Paint

The service life of paints for the same atmospheric environment is also different depending on the type of paint. Paints can be classified by their main component; so-called "binder". Binder is the predominant factor in determining the characteristic of paints. The function of the binder is to give a permanently continuous film which is responsible for adhesion to the surface, resistance to climatic conditions, and mechanical resistance. Paints can be classified into types based on the binders as follows:[12)]

Air-drying resins-Oleoresinous varnishes
Alkyd resins

Chlorinated rubber
Vinyl resins
Expoxy resins
Polyurethane resins
Inorganic resins

Air-drying resins - oleoresinous varnishes: The oils mentioned are reacted or "cooked" with other material, e.g. resin ester gum, coumarone, or phenolic resin. Because the quantity of oil is reduced in these resins, they have much less tendency to "yellowing" than paints based on straight oils. They also have improved weathering characteristics and drying times. The description of this resin is usually based on the amount and type of oil present.

Alkyd resins: Alkyds can be described as synthetic polyesters. They are formed by a reaction between a polycarbonylic fatty acid or its anhydride, a polyhydric alcohol and a vegetable oil or its fatty acid. Properties of alkyds depend on the percentage of oil and also on the alcohol and anhydride used.

Chlorinated rubber: Chlorinated rubber is normally considered to be chlorinated isoprene, but chlorinated polypropylene and chlorinated polyethylene are also often included in this group. These materials are dissolved in aromatic hydrocarbons (e.g. xylol) and are then film-forming in their own right, but they give very brittle films. Another inherent property of the resin is thermoplasticity which makes it unsuitable for use at temperatures above 80°C, and can lead to film defects in very hot climates, where yellowing of pale colors can occur in bright sunlight.

Vinyl resins: Vinyl resins are based on film forming resins consisting of varying ratios of polyvinyl chloride, acetate, and alcohol. Vinyls are soluble in ketones or esters. Generally, the film properties and weathering characteristics are superior to those of chlorinated rubber, but thermoplasticity is still a problem. Vinyl resin based paints are totally unsuitable for application to hand-prepared steel and for brush application, but again show excellent intercoat adhesion characteristics.

Expoxy resins: Expoxies are produced by the condensation polymerization of epichlorhydrin and diphenylolpropane. The reaction conditions and relative proportions of these substances determine the properties of the final product. Because of their water and chemical resistance and high degree of abrasion resistance, expoxy resins are the ideal foundation for many high-performance paint systems. A negative point is that expoxies generally need grit-blasted steel to give good adhesion to the substrate. Expoxies generally have excellent durability but do tend to "yellow" slightly in sunlight. Another problem caused by ultra-violet (UV) radiation is "chalking", but they do not effect the protective characteristics of the system.

Polyurethane resins: Polyurethane resins are polymers formed by the reaction between hydroxy compounds containing isocyanates. Both one-pack and two-pack polyurethanes are used for the protection of steel. The main use of one-pack material is in very low temperature conditions. One defect caused by the properties of these materials is that, due to their high degree of solvent resistance, excellent gloss retention, and lack of reactive sites once the coating is fully cured, it is very difficult to subsequently overcoat, independent of whether the overcoating interval is one week or five years.

Inorganic resins: There are two common inorganic coatings based on silicone. The first of these is based on silicone resins or more correctly, siloxanes - which initially form a coating by solvent evaporation and then, on stoving become highly cross-linked. These properties makes such resins very suitable for high temperature paints. Secondly, there are the silicates which are almost always used in conjunction with zinc dust. Inorganic silicates, based on lithium, potassium, or sodium silicate, and organic silicates, normally based on ethyl silicate, are by far the most commonly used. Coatings based on these resins are very hard, corrosion-resistant, and temperature-resistant.

These kinds of paint have their special properties especially their advantages and their disadvantages. These properties must be considered in the selection of the type of paint in order to get an effective service life.

d) Thickness of paint film

Thickness of paint film also plays a significant role in its service life, the greater the thickness of paint film, the longer the service life. Fig. 3.1 shows the plot indicating the relationship between the thickness of paint film and the percent occurrence of rust. This relation is obtained from the results of exposure test in marine environment near the coast at exposure time 2.5 years.[18] It is clearly seen that percent of rust decreases significantly when the thickness of paint film increases.

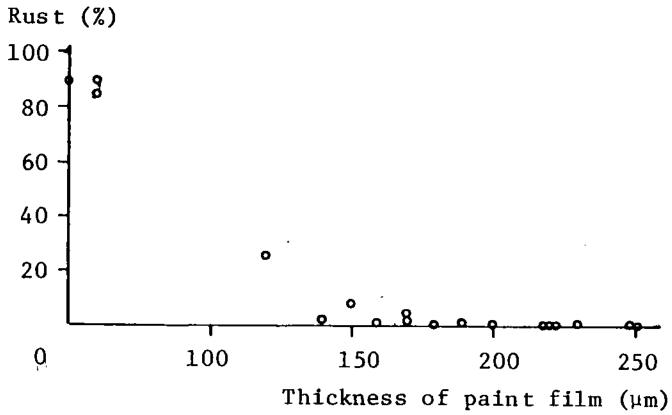


Fig. 3.1 Relation between minimum paint film thickness and the percent occurrence of rust at 2.5 year-exposure time[18]

e) Steel surface preparation

Good surface preparation before painting is essential to obtain maximum service life of paint. A high quality paint may provide poor performance because of a lack of adherence. Two main elements relevant to a proper surface preparation are surface cleanliness and surface roughness. Grease, oil, dirt and rust must be removed to permit good adherence of paint. The roughness of the surface to be painted should be as low as practicable.

For structural steel bridges, grade of surface finish before repainting can be classified into four grades as follows:[23)]

Type 1 - white metal: complete removal of rust, mill scale, and paint residues.
Type 2 - commercial: complete removal of rust, paint residues or other materials except tightly bounded residues. The surface quality obtained may be non uniform as cleanliness or appearance are concerned.
Type 3 - power tool cleaning: removal of all rust and mill free scale. Mill scale tightly bounded rust and paint layer are yet left on the surface.
Type 4 - hand tool cleaning: removal of loose rust and dirt. Active paint layer are still left on the surface.

3.3 SITE INVESTIGATION OF EXISTING BRIDGES

This section aims to determine the service life of paint for bridge structures. As mentioned before, the service life of paint depends on many factors such as atmospheric environments, bridge members, and paint types. Consequently, in order to determine the effect of these factors on the service life of paint, a survey of existing bridges is required.

In general, the degree of deterioration of paint is represented by the "rating number" according to percentages of rust.[20)] The rating number system used in this investigation consists of RN1, RN2, RN3 and RN4. RN4 expresses a state of no rust or new paint. Repainting should be done when the rating number of paint film is lower than two. The definition for each rating number of paint film deterioration is as follows:

RN of paint film deterioration	Meaning
4	No defect or defected area of paint film $<$ 0.03 %
3	0.03 % $\leq$ defected area of paint film $<$ 0.3 %
2	0.3 % $\leq$ defected area of paint film $<$ 5 %
1	defected area of paint film $\geq$ 5 %

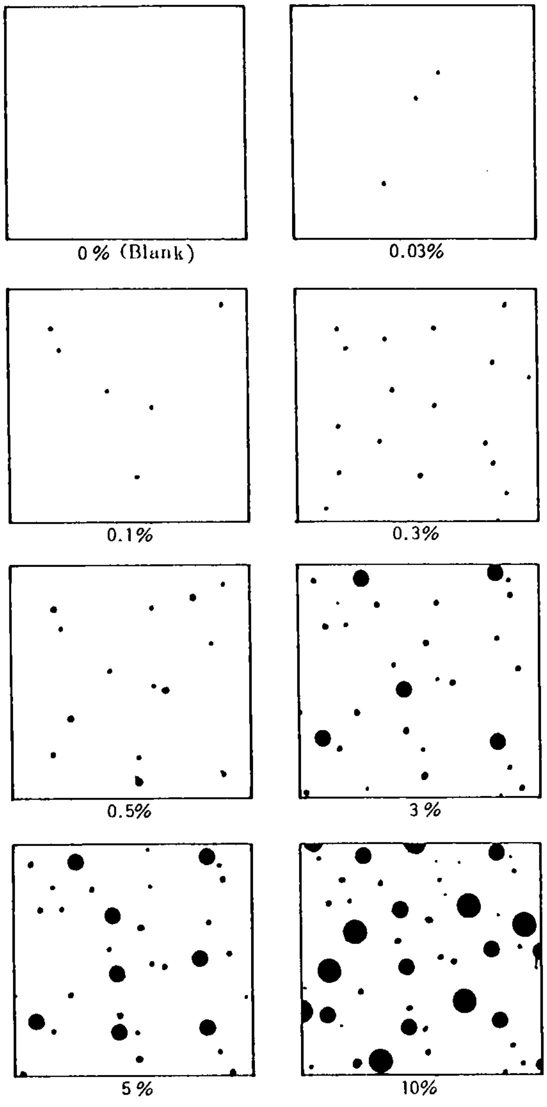
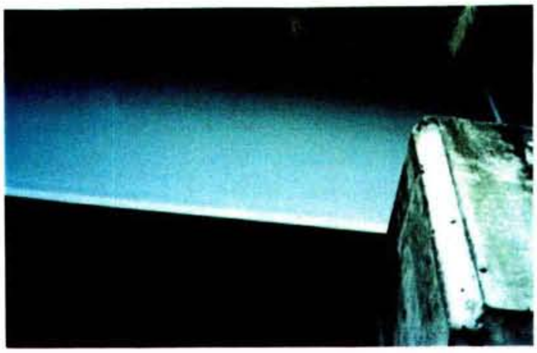
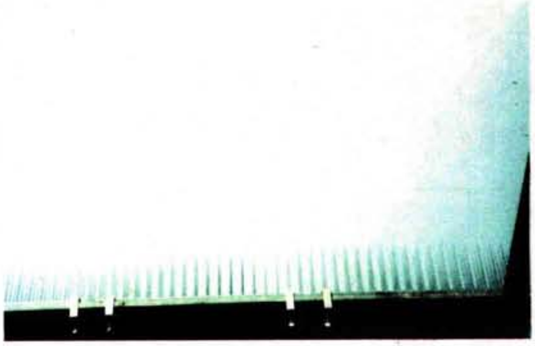


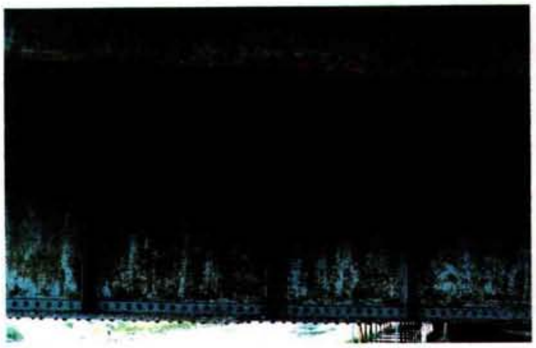
Fig. 3.2 Area percentages of rust





RN 4

RN 3



RN 2

RN 1

Fig. 3.3 Examples of actual condition of paint film for each rating number of paint film deterioration

End part of span of main girders

	External girder	Internal girder
Shoe	P1	P9
Main girder	P2 P3 Outer side P4 P5 Inner side P6 P7 P8	P10 P10 P11 P11 P12 P12 P13

Middle part of span of main girders

	External girder	Internal girder
Main Girder	P15 P16 Outer side P17 P18 Inner side P19 P20 P21	P23 P23 P24 P24 P25 P25 P26
Expan. J.	P14	P22

Note ▒ : Members exposed to rain

Fig. 3.4 The 26 difference parts in a bridge

Note : Defect means rust, blister, crack, and peeling

Fig. 3.2 shows area percentages of defect (rust) for determining the rating number of paint film deterioration. Examples of the actual condition of paint film deterioration for each rating number are shown in Fig. 3.3. Based on this rating number system, data of paint film deterioration of about 250 steel bridges in Japan were collected for each atmospheric environment and bridge member. Bridge members are classified into 26 different parts as shown in Fig. 3.4. These collected data of paint film deterioration are shown in Table A1s to Table A9s in the appendix. Rating number of steel corrosion, which will be discussed later in Chapter 4, are also shown in these tables.

3.4 EVALUATION OF SERVICE LIFE OF PAINT FOR BRIDGE STRUCTURES

Regression equations of paint film deterioration classified by atmospheric environments and bridge members are determined. The regression equation is assumed as a linear expression of the form

$$RN = a + bt \tag{3.1}$$

where RN is rating number, t is exposure time in year. a and b are constants.

The least square method is used for estimating the parameters a and b. Because RN4 expresses the state of new paint. This requires that rating number estimated by Eq. 3.1 must be four at exposure time zero. Thus, the value of the parameter a in Eq. 3.1 has to be four. There is left only the parameter b which should be estimated.

Next, the scattering (standard deviation) of the rating number is assumed to increase proportionally to time. The distribution of rating number is changed into the standard form

$$Z_i = (RN_i - \hat{RN}_i)/t_i \tag{3.2}$$

where RN_i is measured Rating Number. $\hat{RN}_i$ is the expecting rating number. Z is the standard normal distribution $N[0,c^2]$ in which c is the parameter used to estimate a standard deviation in the following equation:

$$\sigma = c\ t \tag{3.3}$$

Fig. 3.5 shows an example of the plot indicating the relationship between rating number of paint film deterioration and exposure time for a certain rural environment (city A). Other examples are shown in the appendix. Circles in the figure represent data of paint film deterioration. Solid line represents a predicting line of rating number from determined regression equation. The dotted line represents the line of μ-3σ of which 99.87 % of

Table 3.2-A Summary of determined service life of paint (year)

Part	A	City B				City C		D	City E		F	City G	
	R.e.	Marine env		City env.		Rural env.		M.e.	C.e.	R.e.	T.e.	Marine env	
No.	Alk.	Alk.	Chl.	Alk.	Chl.	Alk.	Chl.	Alk.	Alk.		Alk.	Alk.	Chl.
P1	2.0	6.8	2.6	5.1	3.9	2.8	3.6	4.6	3.5	3.4	2.5	1.6	2.2
P2	6.1	5.1	4.5	4.8	5.6	4.1	4.8	5.2	6.6	4.2	5.1	2.8	2.3
P3	7.4	4.7	13.4	5.0	3.6	3.5	6.8	5.2	5.1	3.9	5.5	3.4	3.3
P4	8.2	4.7	5.1	5.6	6.4	6.5	7.2	11.1	7.4	4.7	5.7	3.3	2.6
P5	6.6	4.7	5.8	5.5	1.4	4.8	7.3	10.6	10.6	5.7	6.1	3.4	3.5
P6	7.0	-	-	5.1	-	4.0	8.0	-	-	3.7	4.9	4.5	4.6
P7	5.5	-	-	5.4	-	4.3	10.3	-	-	3.2	4.9	2.6	9.6
P8	5.0	3.9	4.4	4.8	5.0	3.6	2.4	4.4	3.9	2.9	3.8	1.7	1.8
P9	4.1	6.8	5.1	5.7	3.2	2.3	3.6	4.7	3.4	-	3.1	1.1	2.5
P10	7.2	4.2	12.7	5.6	4.4	3.6	6.4	6.5	6.3	3.9	4.9	3.4	4.8
P11	7.1	4.7	6.3	5.2	5.0	3.6	6.6	7.4	9.3	5.1	6.8	2.8	3.6
P12	4.8	-	-	6.4	-	4.4	6.9	-	-	2.2	4.0	2.6	9.6
P13	5.0	5.1	4.2	5.4	5.0	3.3	1.9	4.8	3.8	2.4	3.7	1.9	2.0
P14	-	-	-	9.4	-	-	-	-	-	-	-	-	-
P15	6.3	5.1	4.5	5.0	5.6	4.1	4.9	6.7	5.0	4.1	5.0	2.8	2.9
P16	6.5	4.7	4.5	5.0	4.4	3.5	8.0	9.3	6.3	3.9	5.5	3.4	3.9
P17	7.1	5.1	5.6	5.5	7.6	6.5	6.2	7.1	6.6	5.0	6.0	2.7	3.0
P18	6.4	4.7	5.0	5.7	5.8	4.8	6.2	8.7	9.1	5.1	6.7	2.8	3.9
P19	6.7	-	-	5.4	-	4.0	7.0	-	-	5.7	5.0	5.6	6.4
P20	5.3	-	-	6.2	-	5.6	13.9	-	-	5.4	3.6	4.8	9.4
P21	4.5	4.0	12.2	5.1	4.7	3.0	2.6	4.3	3.8	2.8	4.8	1.5	2.0
P22	-	-	-	9.4	-	-	-	-	-	-	-	-	-
P23	6.4	4.2	4.2	5.2	4.4	3.6	8.2	7.4	5.4	4.7	5.2	3.4	10.5
P24	7.0	4.6	4.2	5.5	5.0	3.6	5.2	10.5	10.8	4.9	6.0	2.3	4.0
P25	7.6	-	-	5.3	-	4.4	13.9	-	-	3.2	4.0	4.8	9.4
P26	5.0	3.9	-	5.3	5.0	2.8	2.4	5.7	3.7	2.7	4.2	1.9	1.9
Ave.	6.03	4.83	6.14	5.68	4.78	4.03	6.43	6.90	6.14	4.03	4.88	2.96	4.57

Note R.e.: Rural environment C.e.: City environment
T.e.: Mountainous environment M.e.: Marine environment
Alk.: Alkyd resins Chl.: Chlorinated rubber
Part Nos. refer to Fig. 3.4

Table 3.2-B Number of data used for determining service life of paint in Table 3.25A

Part	A	City B				City C		D	City E		F	City G	
	R.e.	Marine env		City env.		Rural env.		M.e.	C.e.	R.e.	T.e.	Marine env	
No.	Alk.	Alk.	Chl.	Alk.	Chl.	Alk.	Chl.	Alk.	Alk.		Alk.	Alk.	Chl.
P1	16	2	3	9	7	9	10	9	11	31	25	6	13
P2	31	6	5	18	6	10	13	13	18	12	32	8	16
P3	34	6	5	18	5	7	12	11	15	12	30	8	13
P4	36	6	7	21	9	10	13	15	18	13	33	8	16
P5	35	6	7	19	7	10	13	12	15	12	31	8	16
P6	28	-	-	14	-	6	11	-	-	6	26	6	10
P7	22	-	-	7	-	3	9	-	-	5	19	5	9
P8	32	4	6	15	9	10	13	15	17	13	32	7	16
P9	9	2	3	10	5	5	9	7	9	-	15	5	12
P10	29	6	4	19	4	7	13	11	15	12	25	8	12
P10	30	6	4	18	4	7	12	12	15	12	25	8	15
P12	18	-	-	7	-	3	9	-	-	4	15	5	9
P13	27	3	4	14	4	7	10	12	15	12	25	7	15
P14	-	-	-	2	-	-	-	-	-	-	-	-	-
P15	35	6	5	19	6	10	13	12	18	12	32	8	16
P16	35	6	5	18	5	7	12	10	16	12	30	8	13
P17	34	6	7	21	9	10	13	14	18	12	33	8	16
P18	37	6	7	20	7	10	13	12	16	12	31	8	16
P19	21	-	-	5	-	6	9	-	-	6	20	5	9
P20	20	-	-	3	-	4	8	-	-	4	13	4	8
P21	33	5	5	18	8	10	13	15	17	13	32	7	16
P22	-	-	-	2	-	-	-	-	-	-	-	-	-
P23	29	6	4	19	4	7	12	10	15	12	24	8	11
P24	31	5	4	17	4	7	12	11	15	12	24	8	14
P25	15	-	-	2	-	3	8	-	-	3	10	4	8
P26	28	3	-	16	4	7	12	11	15	13	25	7	14

Note R.e.: Rural environment C.e.: City environment
T.e.: Mountainous environment M.e.: Marine environment
Alk.: Alkyd resins Chl.: Chlorinated rubber
Part Nos. refer to Fig. 3.4

the data are located above this line (minimum boundary). Note that the data of water leaky areas were not included in the analysis. Also, data of paint film deterioration in the areas that RN of steel corrosion (Refer to section 4.3-a and Table A1s to Table A9s in the appendix) E, F, G, and G',which correspond to RN 1 of paint film deterioration, were excluded from the analysis because the real exposure time that makes rating number of paint film deterioration equal to one is unclear. From the dotted line in Fig. 3.5 exposure time that makes rating number of paint film deterioration equal to two is defined as service life of paint. Results of the determined regression equations of paint film deterioration and their service life are shown in Table A10s and Fig. A3s in the appendix. Table 3.2 summarizes the service life of paint for each environment.

From these results, it is clearly seen that service life of paint varies depending on the factors such as atmospheric environments, paint types, and parts in a bridge. Service life of paint in marine environment is obviously shorter than service life of paint in other environments. Chlorinated rubber gives a longer service life than alkyd resins. For structural details of a bridge, service life of paint applyed to shoes is extremely shorter than other parts.

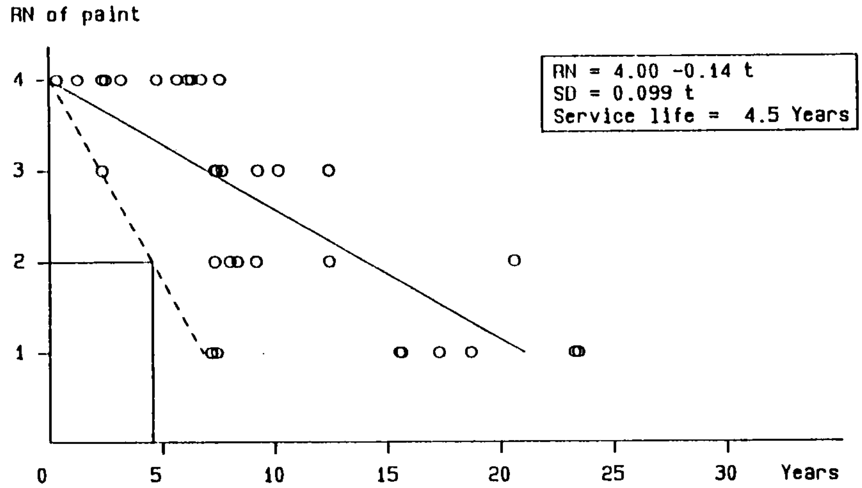


Fig. 3.5 Relation between RN of paint film deterioration and exposure time
P21 Middle part of span of main girder (External girder)
Lower surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=33)

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4 CORROSION CHARACTERISTICS OF STEEL BRIDGES[1)-13)]

4.1 INTRODUCTION

Corrosion is one of the biggest causes of deterioration in steel bridges. About 77 % of the bridges extended in Japan until 1980 by the Hanshin Expressway Public Corporation[14)] are built of steel. In the United States 40 % of the bridges are steel.[15)] Many of these bridges are undergoing deterioration due to corrosion.

The primary cause of corrosion is the accumulation of water and salt on bridge steel. The source of water and salt is either from deck leakage or from the accumulation of road spray and condensation. The rate of corrosion will depend upon various factors such as contaminants in the moisture, dirt, and debris. Past investigations showed that parts of the bridge in which corrosion opts to occur are as follows:[16)-22)]

1. End cross-girders and area surrounding the expansion joints
2. Lower surface at lower flange of both box girders and plate girders
3. Welded parts, bolt joints, and their surrounding areas
4. Lower surface at upper flange of external girders
5. Inner surface of box girders
6. Shoes,bearings and their surrounding areas
7. Areas of water leakage
8. Parts influenced by exhaust gas from vehicles
9. Parts subjected to impaction and abrasion

The consequence of corrosion is the reduction of member size and strength. This in turn, leads to a reduction in the capacity and structural safety.

4.2 PREDICTION OF CORROSION OF PAINTED STEEL MATERIALS

a) Uniform corrosion

Uniform corrosion is the most common form of corrosion, where metal loss takes place uniformly over the entire exposed surface.[23),24)] Uniform corrosion of painted steel materials is predicted based on the steel exposure test and paint life. Corrosion of steel is assumed not to occur during the service life of paint, and after the expiration of paint life, the corrosion mechanism of painted steel materials is assumed to be the same as of bare steel in the steel exposure test.

Fig. 4.1 illustrates the concept of these assumptions. If $g(t)$ is a

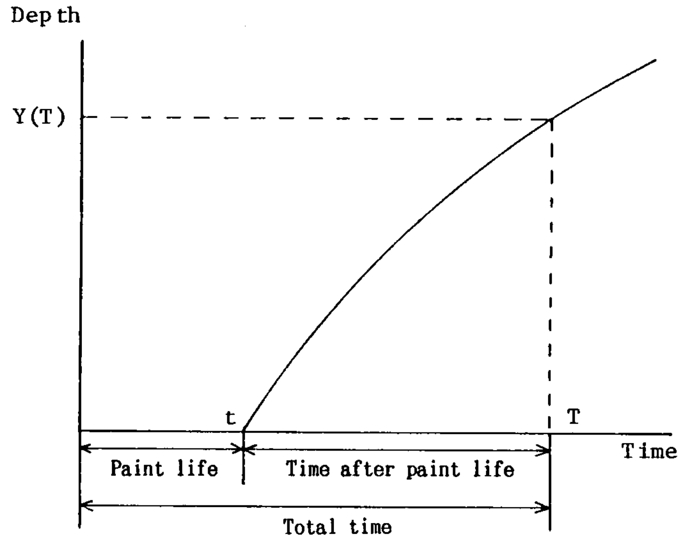


Fig. 4.1 Conceptual diagram of corrosion behavior of painted steel materials

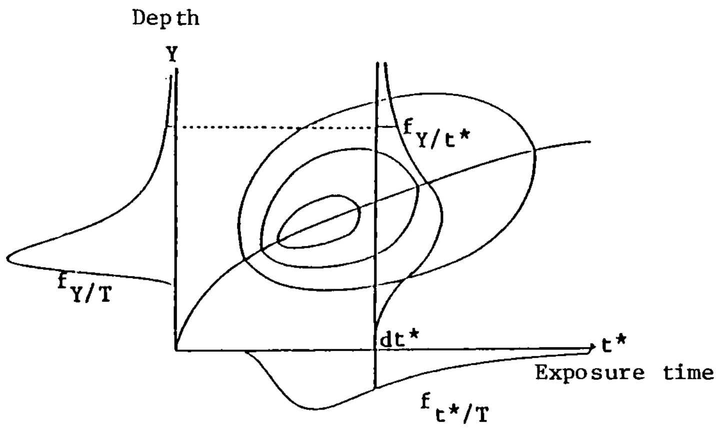


Fig. 4.2 Conceptual diagram for predicting uniform corrosion depth

probability density function of paint life, then the conditional probability of t^*, which is the exposure time of the steel surface after the expiration of paint life, can be expressed as follows:

$$f_{t^*/T}(t^*/T) = g(T-t^*) \tag{4.1}$$

Here $f_{t^*/T}$ is the conditional probability density function of exposure time to the atmosphere of the steel surface. T is total time after painted. The exposure time of the steel surface to the atmosphere is applied to Eq. 2.18 in order to determine corrosion of painted steel materials.

However, at any exposure time of steel surface t^*, there is a distribution (scattering) of corrosion depth as shown in Fig. 4.2. The estimated result of corrosion from Eq. 2.18 can represent only the mean value of this distribution. In calculation, the shape of distribution as well as the degree of scattering must be assumed. Because the negative value of corrosion basically has no physical meaning, the distribution of corrosion depth is assumed to be a log-normal distribution. Consequently, the conditional probability of corrosion depth at any time T after construction, $P(Y_i/T)$, can be determined by the following equation:

$$\begin{aligned} P(Y_i/T) &= f_{Y_i/T}(Y_i/T)\ dY \\ &= \int_0^\infty f_{Y_i/t^*}(Y_i/t^*)\ f_{t^*/T}(t^*/T)\ dt^* dY \end{aligned} \tag{4.2}$$

in which $f_{Y/t}$ represents the conditional probability density function of corrosion depth of bare steel. $f_{Y/T}$ represents the conditional probability density function of corrosion depth of painted steel.

Furthermore, the mean value and standard deviation of predicted corrosion depth can be estimated by Eq. 4.3 and Eq. 4.4. respectively.

$$\mu_Y = \int_0^\infty Y\ f(Y/T_i)\ dY \tag{4.3}$$

$$\sigma_Y^2 = \int_0^\infty Y^2 f(Y/T_i)\ dY - \mu_Y^2 \tag{4.4}$$

b) Maximum and/or local corrosion

Corrosion depth estimated in the previous section is uniform corrosion. From this result, maximum value of corrosion depth is estimated based on the mean value and standard deviation of the distribution of this uniform corrosion by the following equation:

$$Y_{max} = \mu_y + 3\sigma_y \tag{4.5}$$

However, past investigations showed that the rate of maximum pit depth changes rapidly when uniform corrosion depth reaches a certain value. This value may be called " a triggered value". After that, a state of maximum corrosion will change to local corrosion. This triggered value was reported as

0.7-1.3 mm[25] for marine steel structures. After that, the local corrosion speed is about four times the uniform corrosion speed. Based on this corrosion property of marine steel structures, maximum and/or local corrosion of painted steel materials is predicted based on the following assumptions:

1) Local corrosion will develop when uniform corrosion depth reaches a triggered value. The distribution of this triggered value is a log-normal distribution of which the mean value is 0.7 mm., and the coefficient of variation is 0.15.

2) When uniform corrosion depth is less than the triggered value, maximum pit depth is estimated by Eq. 4.5; when uniform corrosion depth is greater than the triggered value, local corrosion speed is four times the uniform corrosion speed.

Fig. 4.3 illustrates the concept of maximum and/or local corrosion.

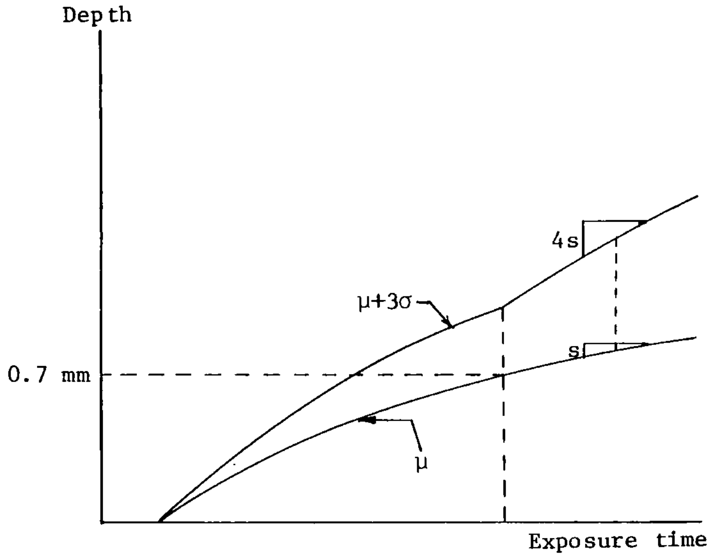


Fig. 4.3 Conceptual diagram for predicting maximum and/or local corrosion depth

4.3 SITE INVESTIGATION OF EXISTING BRIDGES

a) Corrosion deterioration of bridge members

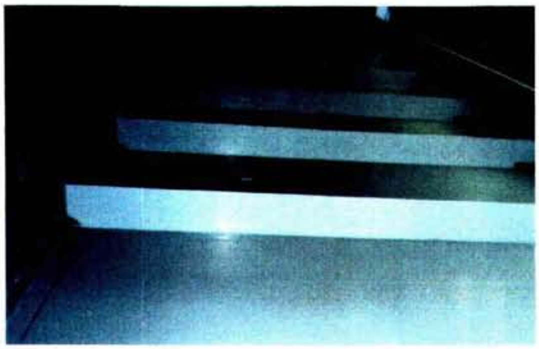
One of the main objects of this research is to clarify the corrosion deterioration characteristics of structural steel bridges. In general, corrosion of painted bridge members will occur after the expiration of paint life. Normally, corrosion of painted steel materials can be predicted based on steel exposure test and paint life. However, corrosion deterioration characteristics of bridge members are different from normal painted steel materials depending on many factors such as the parts of a bridge. The above predicting model of corrosion depth cannot apply directly to bridge structures. Consequently in order to clarify the corrosion deterioration characteristics of bridge structures, a survey of corrosion deterioration of existing bridges is required.

Corrosion deterioration of existing bridges is qualitatively measured by means of rating number. The rating number system for steel corrosion used in this survey consists of eight steps that are A, B, C, D, E, F, G, and G'. The meaning of each step is illustrated as follows:

RN of steel corrosion	Meaning
A	Spot rust < 0.5 % of area or no rust
B	0.5 % $\leq$ Spot rust < 10 % of area
C	10 % $\leq$ Spot rust < 50 % of area
D	50 % $\leq$ Spot rust < 90 % of area
E	Spot rust $\geq$ 90 % of area or uniform corrosion over the surface
F	Initial local corrosion
G	Severe local corrosion, steel corrodes less than half of its thickness corrosion depth about 3 mm
G'...........	very severe local corrosion, steel corrodes more than half of its thickness corrosion depth about 10 mm

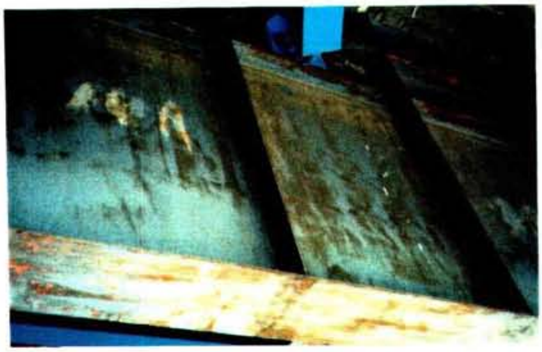
Note: No local corrosion for RN of A to E.

Examples of actual condition of steel corrosion for each rating number are shown in Fig. 4.4. Based on this rating number system, corrosion deterioration of 216 road bridges and 33 railway bridges in each environment were qualitatively measured for 26 different parts of a bridge. These collected data of steel corrosion for each environment and bridge member are shown in Table A1s to Table A9s in the appendix together with the data of paint film deterioration. Table A11s show the history of paint for each bridge. Fig. 4.5 shows one example of the plot showing the relationship between RN of steel corrosion and accumulated exposure time after paint life. White circles represent the data of normal areas while black circles represent the data of water leaky areas. Exposure time is the accumulated time after paint life.

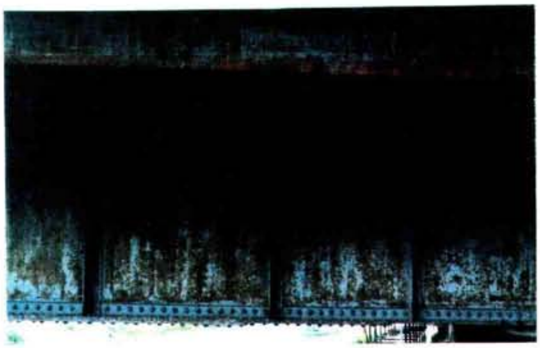


RN A

RN B



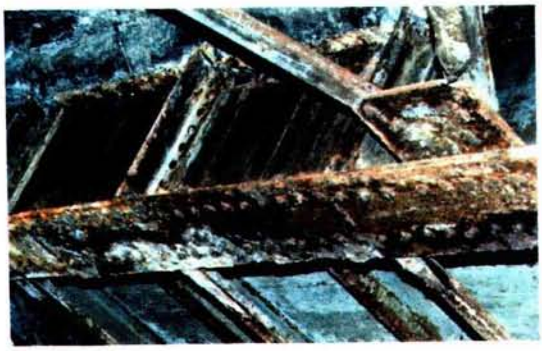
RN C



RN D

RN E

RN F



RN G

RN G'

Fig. 4.4 Examples of actual condition of steel surface for each rating number of steel corrosion

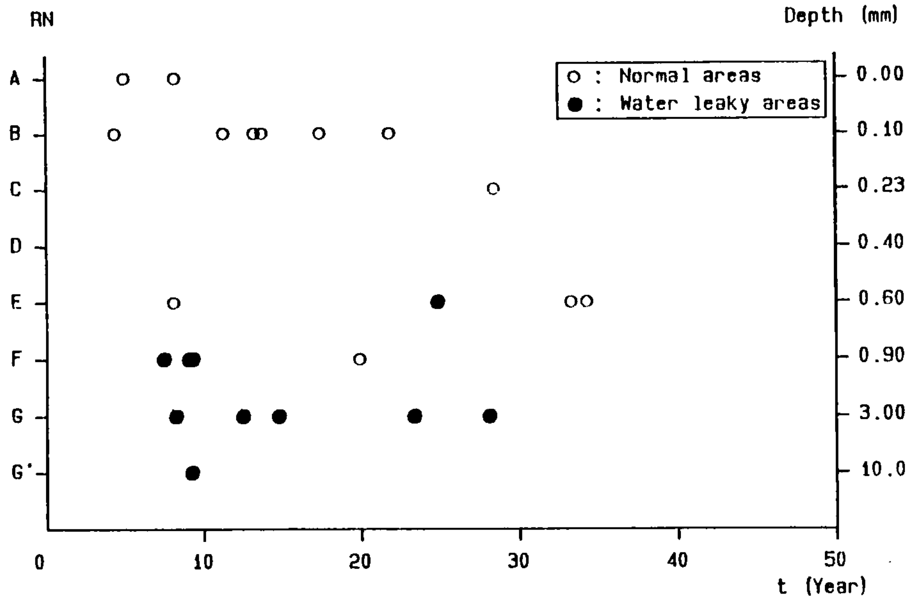


Fig. 4.5 Relation between RN of steel corrosion and exposure time
P3 End part of span of main girder (External girder)
Lower surface of upper flange - Inner side (City A, Rural envi.)
Exposure time = accumulated time after paint life (N=14)

b) Relationship between qualitative data of corrosion deterioration and corrosion depth

Data of corrosion deterioration collected in the previous section are qualitative data. In order to use these data for analysis, it is necessary to convert these qualitative data to quantitative data. Here, RN F represents the state of initial local corrosion that can be observed by eye, and corrosion depth of RN F should be greater than corrosion depth at the actual state of local corrosion that was reported as 0.7 mm.[25] Consequently, the corrosion depth of 0.7mm should fall between RN E and RN F. Based on this consideration, corresponding corrosion depth for RN of A to F are converted regarding to the assumption that the degree of corrosion deterioration increases gradually from A to F. These assumed corresponding corrosion depths are shown by vertical axis in the right-hand side of Fig. 4.5.

In order to examine the reliability of the above assumed corresponding corrosion depth, the plate thickness of 80 samples of corroded bridge members and scrap materials were measured by ultrasonic measuring instruments (Kawatetsu Model IT-6S and IT-7S). The principle of the ultrasonic measuring instrument is shown in Fig. 4.6.[26] These 80 samples of corroded materials include 43 samples from road bridges, 32 samples from railway bridges, and 5 samples from scrap materials. The samples were selected for each combination of rating number of steel corrosion. Residual paint layer and rust were removed from both side of the sample by hand scraper before measuring (Fig.

4.7). The measured area for each sample is approximately 10 cm x 10 cm for the web plate, and 5 cm x 20 cm for the flange plate (Fig. 4.8). Within the measured area, plate thickness was measured at approximately 1 cm intervals in two directions. Each point was measured two or three times to get the exact thickness.

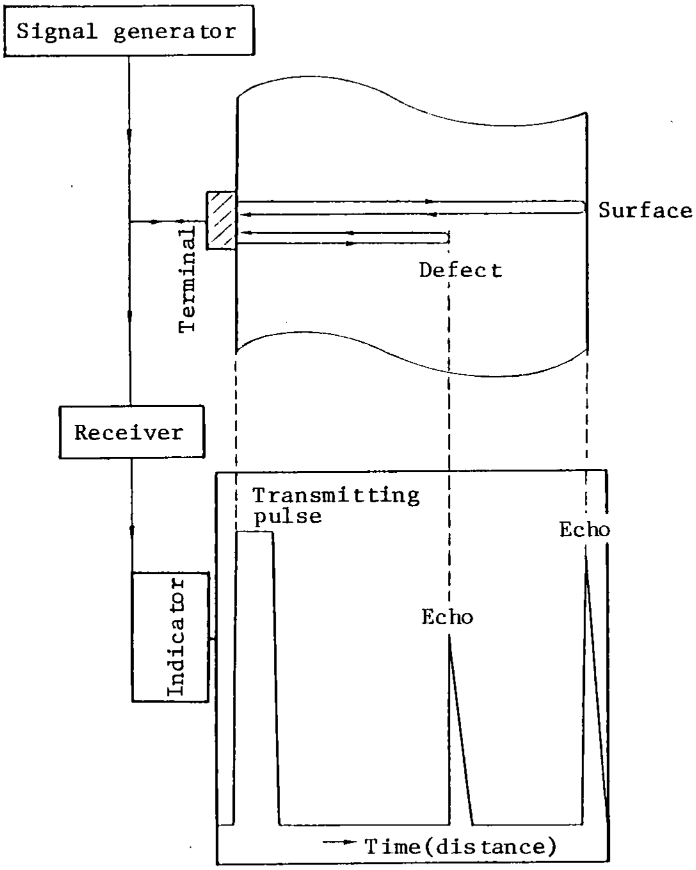


Fig. 4.6 Principle of the ultrasonic measuring instrument[26)]

From these results, corrosion depth (of both sides) for each measured point was determined with reference to the original plate thickness. Original plate thickness was obtained by measuring the plate thickness within the same plate near the sample in the area that no corrosion occured for both sides of the plate. Design value of the steel plate was not used as an original plate thickness because the actual plate thickness may be different from the design plate thickness due to error in the manufacturing process. The maximum value of corrosion depth among several measured points in the measured area is defined as maximum corrosion depth for each sample. Results of the plate measurement of 80 samples are shown in Table 4.1 to Table 4.3. Fig. 4.9 is the

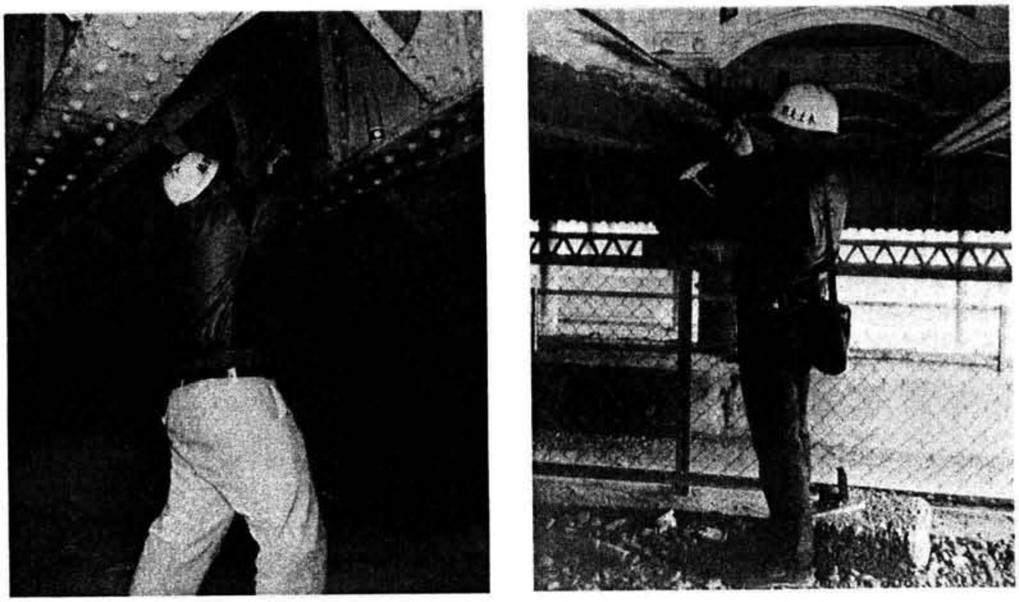


Fig. 4.7 Removal of residual paint layer and rust and measurement of plate thickness

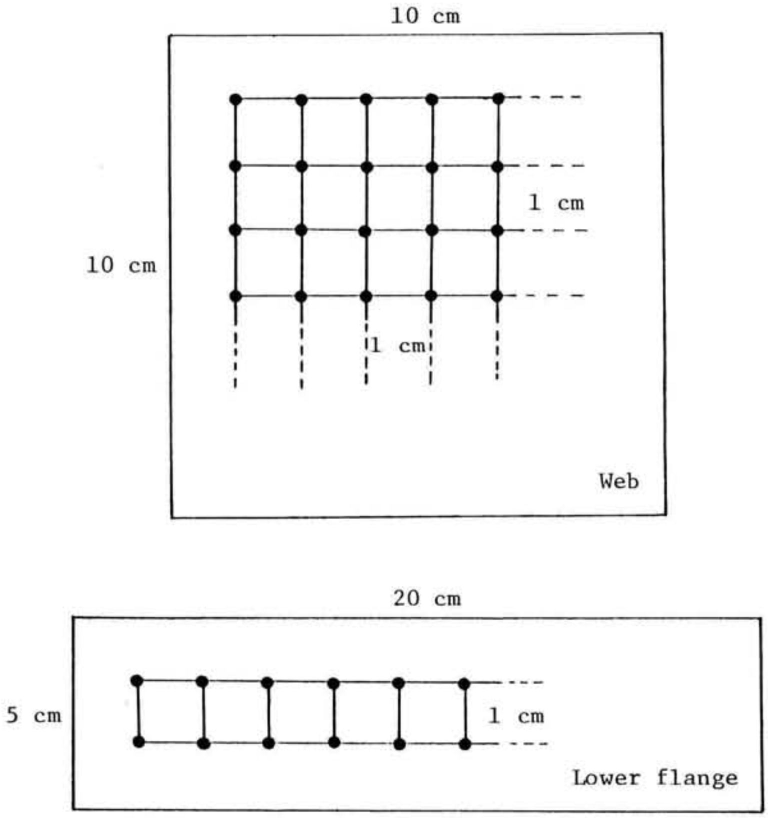


Fig. 4.8 Diagram showing the measured points of steel plate

Table 4.1 Measured results of corroded steel plates 1
Road bridges

Sample No.	Original plate thickness (mm)	RN	Minimum plate thickness (mm)	Max. corrosion depth (mm)
1	9,70	B−B	9.50	0.20
2	9.80	A−B	9.55	0.25
3	10.30	B−C	10.10	0.20
4	9.75	B−B	9.50	0.25
5	10.05	B−C	9.60	0.45
6	9.75	A−B	9.60	0.15
7	9.30	A−A	9.15	0.15
8	9.80	D−G	6.30	3.50
9	9.80	A−C	9.55	0.25
10	9.85	A−C	9.65	0.20
11	9.50	A−B	9.40	0.10
12	9.50	D−F	8.45	1.05
13	10.00	C−C	9.40	0.60
14	9.50	D−F	7.80	1.70
15	9.50	B−C	9.25	0.25
16	9.80	C−D	9.05	0.75
17	9.70	B−C	9.05	0.65
18	9.90	C−C	9.05	0.85
19	9.90	B−B	9.65	0.25
20	10.30	B−E	9.45	0.85
21	9.40	A−A	8.65	0.75
22	10.30	A−C	10.05	0.25
23	10.20	B−C	9.90	0.30
24	9.75	B−B	9.50	0.25
25	9.80	E−G	5.50	4.30
26	9.75	C−F	8.90	0.85
27	9.75	C−C	9.20	0.55
28	9.60	B−C	9.30	0.50
29	10.20	A−B	10.00	0.20
30	9.95	A−B	9.80	0.15
31	9.40	A−B	9.25	0.15
32	9.80	C−C	9.30	0.50
33	9.80	G−G	2.50	7.30
34	9.85	C−D	8.90	0.95
35	9.90	C−E	8.40	1.50
36	9.20	A−A	9.10	0.10
37	9.60	D−D	8.80	0.80
38	9.60	D−D	8.70	0.90
39	9.50	B−D	8.80	0.70
40	9.80	B−D	9.50	0.30
41	9.80	F−G	6.75	3.05
42	9.75	F−F	8.10	1.65
43	9.90	E−F	8.90	1.00

Table 4.2 Measured results of corroded steel plates 2
Railway bridges

Sample No.	Original plate thickness (mm)	RN	Minimum plate thickness (mm)	Max. corrosion depth (mm)
1	8.70	A−A	8.55	0.15
2	8.70	A−A	8.60	0.10
3	8.90	A−A	8.80	0.10
4	8.95	A−A	8.90	0.05
5	8.80	A−A	8.70	0.10
6	8.90	A−A	8.80	0.10
7	9.00	A−A	8.90	0.10
8	9.00	A−B	8.80	0.20
9	10.80	A−C	10.50	0.30
10	10.15	A−C	9.80	0.35
11	10.00	A−D	9.50	0.50
12	10.70	A−C	10.40	0.30
13	10.00	A−E	9.35	0.65
14	9.90	A−E	9.10	0.80
15	10.45	A−D	9.90	0.55
16	10.00	A−D	9.50	0.50
17	11.00	B−B	10.55	0.45
18	11.00	B−B	10.60	0.40
19	9.50	B−C	9.05	0.45
20	9.70	A−E	9.30	0.40
21	10.00	B−E	9.30	0.70
22	9.40	B−B	9.10	0.30
23	9.50	B−C	9.10	0.40
24	11.00	B−E	10.15	0.85
25	10.85	B−E	10.20	0.65
26	9.90	A−B	9.60	0.30
27	9.80	A−B	9.60	0.20
28	10.00	A−B	9.80	0.20
29	9.90	A−B	9.75	0.15
30	10.00	A−C	9.75	0.25
31	10.00	A−B	9.80	0.20
32	9.90	A−A	9.80	0.10

Table 4.3 Measured results of corroded steel plates 3
Scrap materials

Sample No.	Original plate thickness (mm)	RN	Minimum plate thickness (mm)	Max. corrosion depth (mm)
1	24.90	A−A	24.75	0.15
2	24.90	A−B	24.80	0.10
3	24.90	A−C	24.40	0.50
4	24.90	A−D	24.20	0.70
5	24.90	A−E	24.25	0.65

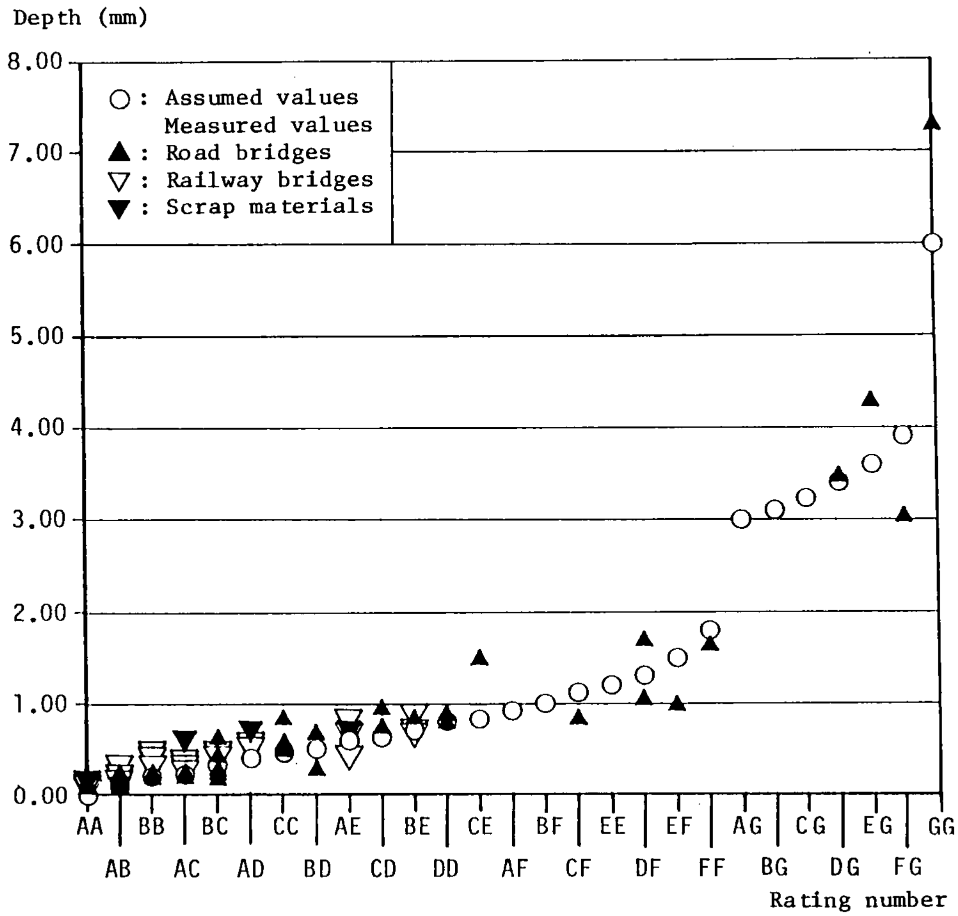


Fig. 4.9 Maximum corrosion depth for each combination of rating number of steel corrosion (both sides of steel plate)

plot showing maximum corrosion depth for each combination of rating number of steel corrosion with the comparison of assumed values. Measured values accord well with assumed values in this figure.

Next, the measured data of maximum corrosion depth for each combination of rating number of steel corrosion were applied into Eq. 4.6, and by the multiple linear regression analysis, maximum corrosion depth for each rating number were determined.

$$M = \bar{A}\, n_A + \bar{B}\, n_B + \bar{C}\, n_C + \bar{D}\, n_D + \bar{E}\, n_E + \bar{F}\, n_F + \bar{G}\, n_G \qquad (4.6)$$

where M represents maximum corrosion depth for both sides of the steel plate (mm). $\bar{A}$ - $\bar{G}$ represent maximum corrosion depth for the rating number of A to G (mm). n_A- n_G represent the number of steel surfaces that the rating number is A to G (0, 1, or 2).

Table 4.4 Corresponding corrosion depth for each RN of steel corrosion

Rating number	A	B	C	D	E	F	G	G'
Assumed values (mm)	0.00	0.10	0.23	0.40	0.60	0.90	3.00	10.0
Measured values (mm)	0.05	0.13	0.30	0.47	0.67	0.63	3.38	-

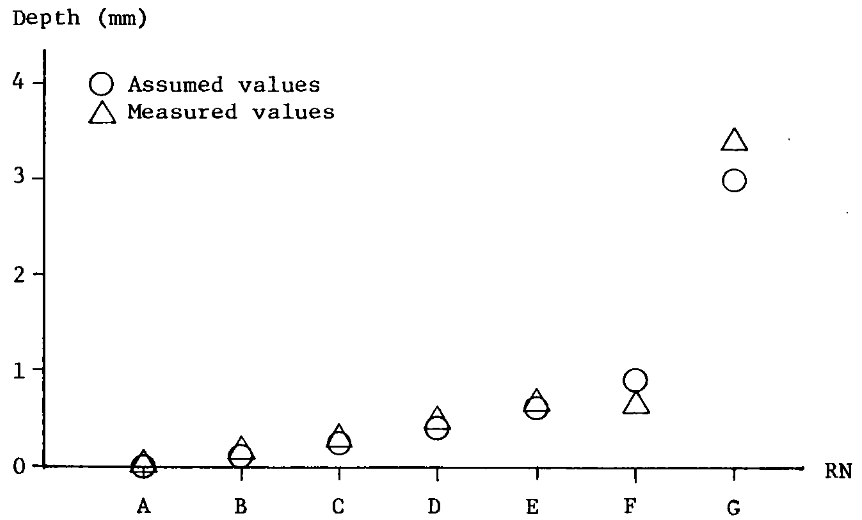


Fig. 4.10 Maximum corrosion depth for each rating number of steel corrosion

Table 4.4 and Fig. 4.10 show the results of determined maximum corrosion depths with the comparison of assumed values. Note that data No. 21 in Table 4.1 was excluded from the analysis because this data is obviously too big (reference to its rating number). This may be the effect of defect such as voids or cracks that are embedded inside the materials. From these results, for rating number of A, B, C, D, E, and G, measured maximum corrosion depth accord well with assumed maximum corrosion depth. For RN of F, measured value is too small to compare with the assumed value. One consideration reason is that the width of the initial local corrosion is still too small to compare with the terminal of a measuring instrument that has the diameter of 1 cm. Therefore the terminal of the measuring instrument could not reach the bottom of local corrosion, and the exact value of corrosion depth could not be obtained.

4.4 INVESTIGATION ON CORROSION CHARACTERISTICS OF STEEL BRIDGES

Qualitative data of corrosion deterioration from surveying (data in Table A1 to Table A9) are converted to corrosion depth by the relation in section 4.3 b. From this result, the relationship between corrosion depth and exposure time for each environment and bridge member is determined. The relationship is assumed to obey the kinetic relation $Y = k\ t^m$. Where Y represents maximum corrosion depth, t represents accumulated exposure time of steel surface after paint life. k and m are constants.

Data of steel corrosion (corrosion depth) are classified into three classes. Class one consists of the data of corrosion depth of bridges that have never been repainted. Class two consists of the data in class one plus the data of corrosion depth of bridges that have been repainted, and the paint history is known. Class three consists of data in class one plus the data of corrosion depth of bridges that have been repainted, but part of the paint history is unclear. For data class three, normally the data of the first paint and the last paint are known, but the paint history during the first paint and the last paint is unclear. In this case, the paint interval between each cycle of paint is assumed based on the degree of bridge maintenance, the exposure time after the last paint, and the degree of deterioration of the bridge.

Accumulated exposure time of the steel surface after paint life, t_{acc}, is determined by the following equation:

$$t_{acc} = \sum_{i=1}^{n} t^*_i \tag{4.7}$$

$$t^* = T - t \geq 0$$

where T represents time after painted for each cycle of paint.
t represents service life of paint obtained from section 3.4,
n represents the number of paint cycles.

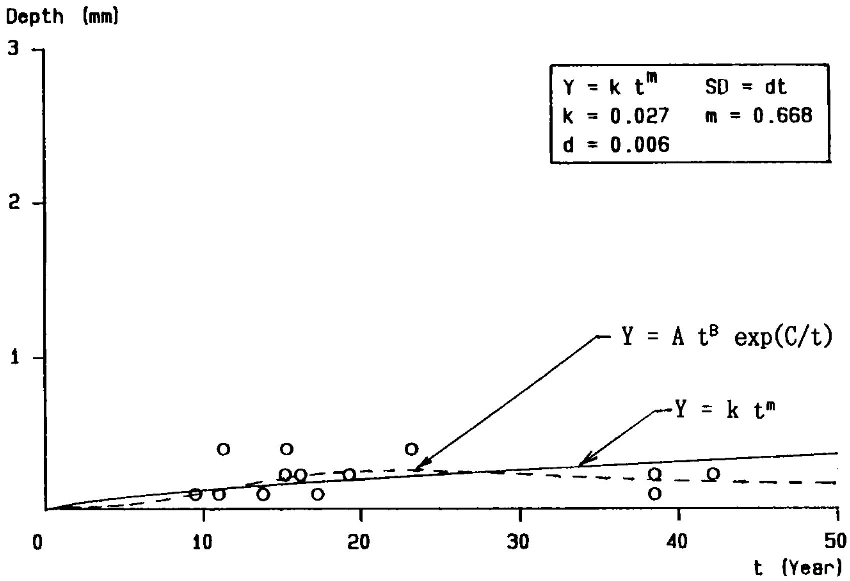


Fig. 4-11 Relation between corrosion depth and exposure time (Class 2)
P6 End part of span of main girder (External girder)
Upper surface of lower flange - Outer side (City B, City envl.)
Exposure time = accumulaied time after paint life

Table 4.5 Predicted maximum corrosion depth of bridge members at exposure time of 10 years for each environments (mm)
Exposure time = accumulated time after paint life
Data class 1 (good data - no repaint)

Part No.	City A Rural	City B Marine	City B City	City C Rural	City D Marine	City E City	City E Rural	City F Mount.	City G Marine
P1	.42 7	.26 4	.40 7	.25 12	.18 3	-	-	.27 15	.74 4
P2	.15 9	.19 5	.09 4	.03 12	.09 4	-	-	.06 14	.25 4
P3	.10 6	.26 3	.17 3	.03 8	.07 3	-	-	.04 14	.30 3
P4	.15 8	.13 7	.07 7	.03 10	-	-	-	.03 15	.29 5
P5	.16 9	.19 7	.09 5	.03 10	-	-	-	.03 14	.22 5
P6	.13 5	.35 1	.10 2	.04 8	-	-	-	.07 12	-
P7	.23 6	.35 1	.25 2	-	-	-	-	.08 8	-
P8	.19 10	.23 7	.26 7	.07 13	.18 4	-	-	.09 16	.54 5
P9	.59 4	.67 3	.20 3	.18 7	.21 2	-	-	.28 8	.71 3
P10	.12 6	.20 3	.11 3	.04 8	.21 2	-	-	.04 11	.16 2
P11	.15 5	.26 5	.08 3	.04 8	.36 3	-	-	.03 11	.13 3
P12	.11 5	-	.11 1	.08 5	-	-	-	.10 6	-
P13	.15 7	.25 5	.19 3	.12 10	.44 3	-	-	.07 12	.41 3
P14	-	-	.33 1	-	-	-	-	-	-
P15	.13 9	.17 5	.09 4	.03 12	.22 3	-	-	.05 14	.25 4
P16	.14 9	.17 5	.16 4	.04 7	-	-	-	.04 14	.13 3
P17	.13 8	.15 7	.06 7	.03 11	.26 3	-	-	.03 15	.10 5
P18	.09 10	.15 7	.08 5	.03 11	.07 2	-	-	.03 14	.10 5
P19	.19 5	-	.10 1	.05 7	-	-	-	.17 6	-
P20	.25 6	-	-	-	-	-	-	.20 3	-
P21	.15 10	.41 5	.24 7	.07 13	.52 4	-	-	.09 15	.37 5
P22	-	-	-	-	-	-	-	-	-
P23	.11 7	.18 5	.11 3	.04 7	.28 2	-	-	.03 11	-
P24	.08 6	.16 5	.09 3	.04 8	-	-	-	.03 11	-
P25	.23 2	-	-	-	-	-	-	.22 3	-
P26	.15 8	.36 3	.22 3	.07 10	.23 3	-	-	.07 12	.44 2
Ave.	.15	.23	.14	.05	.23	-	-	.07	.24
Ave.	.15	.23	.15	.04	.25	-	-	.07	.30

①	.04	.09	(.10)	.08	(.17)	-	-	.04	.14
②	(.25)	(.33)	(.32)	.14	(.29)	-	-	(.11)	(.31)

Note ① : Compare with the results of steel exposure test underneath bridges
② : Compare with the results of steel exposure test exposed to rain
Values in the right hand side represent the number of data.
Part Nos. refer to Fig. 3.4

Table 4.6 Predicted maximum corrosion depth of bridge members at exposure time of 10 years for each environments (mm)
Exposure time = accumulated time after paint life
Data class 2

Part No.	City A Rural	City B Marine	City B City	City C Rural	City D Marine	City E City	City E Rural	City F Mount.	City G Marine
P1	-	.29 9	.39 21	-	.11 6	-	-	.22 22	.66 12
P2	-	.16 10	.13 20	-	.09 11	-	-	.06 15	.21 11
P3	-	.17 8	.14 19	-	.07 3	-	-	.05 16	.22 5
P4	-	.14 12	.11 24	-	-	-	-	.03 17	.20 9
P5	-	.17 12	.13 23	-	-	-	-	.04 17	.18 8
P6	-	.19 2	.12 13	-	-	-	-	.08 14	.13 3
P7	-	.19 2	.26 9	-	-	-	-	.10 10	.20 3
P8	-	.24 12	.21 26	-	.13 9	-	-	.10 21	.38 14
P9	-	.35 8	.20 17	-	.10 6	-	-	.25 12	.70 8
P10	-	.17 7	.14 19	-	.21 2	-	-	.05 14	.15 4
P11	-	.19 10	.13 20	-	.36 3	-	-	.04 12	.18 7
P12	-	-	.22 8	-	-	-	-	.11 9	.20 3
P13	-	.25 10	.19 20	-	.20 7	-	-	.08 16	.41 12
P14	-	.15 2	.22 3	-	-	-	-	-	-
P15	-	.17 10	.13 21	-	.22 3	-	-	.05 16	.21 9
P16	-	.18 10	.14 20	-	-	-	-	.04 16	.13 5
P17	-	.14 12	.10 23	-	.19 4	-	-	.03 17	.14 9
P18	-	.16 12	.12 23	-	.07 2	-	-	.04 16	.13 9
P19	-	-	.11 4	-	-	-	-	.14 8	.13 3
P20	-	-	.17 3	-	-	-	-	.16 4	.15 2
P21	-	.31 10	.19 26	-	.25 6	-	-	.08 17	.34 14
P22	-	.15 2	.27 2	-	-	-	-	-	-
P23	-	.18 10	.14 20	-	.28 2	-	-	.04 13	.15 3
P24	-	.18 10	.12 20	-	-	-	-	.04 12	.22 6
P25	-	-	.16 2	-	-	-	-	.22 3	.15 2
P26	-	.28 7	.18 20	-	.23 3	-	-	.08 14	.51 11
Ave.	-	.19	.17	-	.20	-	-	.08	.21
Ave.	-	.19	.15	-	.18	-	-	.07	.22

①	-	.09	(.10)	-	(.17)	-	-	.04	.14
②	-	(.33)	(.32)	-	(.29)	-	-	(.11)	(.31)

Note ① : Compare with the results of steel exposure test underneath bridges
② : Compare with the results of steel exposure test exposed to rain
Values in the right hand side represent the number of data.
Part Nos. refer to Fig. 3.4

Table 4.7 Predicted maximum corrosion depth of bridge members at exposure time of 10 years for each environments (mm)
Exposure time = accumulated time after paint life
Data class 3 (bad data - all data)

Part No.	City A Rural	City B Marine	City B City	City C Rural	City D Marine	City E City	City E Rural	City F Mount.	City G Marine
P1	.37 21	-	-	.24 14	-	.13 8	.15 6	-	-
P2	.15 20	-	-	.04 14	-	.08 4	.05 6	-	-
P3	.10 14	-	-	.05 10	-	.06 3	.04 5	-	-
P4	.13 17	-	-	.03 10	-	.07 4	.05 4	-	-
P5	.14 15	-	-	.04 11	-	-	.10 1	-	-
P6	.11 12	-	-	.04 9	-	-	.06 5	-	-
P7	.16 14	-	-	-	-	-	.08 3	-	-
P8	.15 23	-	-	.08 15	-	.09 14	.05 11	-	-
P9	.34 13	-	-	.19 9	-	.11 7	.29 2	-	-
P10	.13 14	-	-	.05 10	-	.06 5	.04 5	-	-
P11	.12 13	-	-	.05 9	-	.07 1	.07 2	-	-
P12	.15 14	-	-	.08 5	-	-	.11 3	-	-
P13	.14 19	-	-	.11 12	-	.10 11	.08 10	-	-
P14	-	-	-	-	-	-	-	-	-
P15	.12 17	-	-	.04 14	-	.07 5	.05 6	-	-
P16	.14 17	-	-	.05 8	-	.05 4	.04 5	-	-
P17	.13 14	-	-	.03 12	-	.06 5	.08 3	-	-
P18	.10 16	-	-	.04 13	-	.07 1	.10 1	-	-
P19	.18 9	-	-	.06 8	-	-	.10 1	-	-
P20	.21 9	-	-	-	-	-	.05 1	-	-
P21	.14 22	-	-	.09 16	-	.09 13	.05 11	-	-
P22	-	-	-	-	-	-	-	-	-
P23	.11 15	-	-	.05 8	-	.07 6	.05 5	-	-
P24	.10 14	-	-	.05 10	-	-	.06 4	-	-
P25	.23 6	-	-	-	-	-	.04 1	-	-
P26	.13 21	-	-	.08 13	-	.10 12	.05 8	-	-
Ave.	.13	-	-	.06	-	-	-	-	-
Ave.	.13	-	-	.05	-	.08	.06	-	-

①	.04	-	-	.08	-	-	-	-	-
②	(.25)	-	-	.14	-	(.32)	(.25)	-	-

Note ① : Compare with the results of steel exposure test underneath bridges
② : Compare with the results of steel exposure test exposed to rain
Values in the right hand side represent the number of data.
Part Nos. refer to Fig. 3.4

The relationship between corrosion depth and exposure time is determined for 26 different parts of a bridge such as shoe, expansion joint, web and flange of main girder. The data of bridges that t_{acc} equal to zero are excluded from the analysis. Fig. 4.11 shows an example of the relationship for data class two of bridges in city B (city environment). The other examples are shown in the appendix. Note that data of water leaky areas are excluded from the analysis. Dotted line represents the long-term corrosion determined by the equation of Horikawa. It is clearly seen that the equation of Horikawa cannot give a accurate proof that corrosion depth does not decrease when exposure time increases. Therefore, the equation of Horikawa is not used for the analysis. Results of the determined relationship between corrosion depth and exposure time for each environment and bridge member are shown in Table A12 in the appendix. From these results, maximum corrosion depth at exposure time of ten years are determined for each environment and bridge member. The results are summarized in Table 4.5 to Table 4.7. It is clearly shown that the most corrosive environment is marine environment. In each environment, the most corrosive parts of a bridge among 26 different parts are shoes of both external girder and internal girder.

4.5 PREDICTION OF CORROSION OF BRIDGE MEMBERS

The corrosion process of painted bridge members is assumed to be the same as of normal painted steel materials. The relationship between corrosion of painted bridge members and corrosion of painted steel materials is assumed as the following equation:

$$Y(T) = r\ Y(t^{*}) \tag{4.8}$$

where Y(T) represents corrosion of bridge members, which is the function of total exposure time. $Y(t^{*})$ represents corrosion of steel materials based on steel exposure and paint life, which is the function of exposure time of steel surface after paint life. r represents corrosion ratio.

Corrosion of bridge member and corrosion of painted steel materials must be obtained for the same atmospheric condition. Corrosion of bridge members are obtained from the results of bridge survey. Corrosion of painted steel materials are determined based on steel exposure test and paint life for each environment of bridges by the model in section 4.3. If there are the results of steel exposure test in the same environment of surveyed bridges, these results of steel exposure test will be used directly. If there is no result of steel exposure test in the same environment of surveyed bridges, corrosion behavior of bare steel will be determined based on environmental factors by the Eq. 2.18 to Eq. 2.27. Environmental factors for each environment of bridges are shown in Table 4.8. Table 4.9 shows the results of determined parameter k and m in the equation for predicting long-term corrosion of bare steel (Eq. 2.18).

Table 4.8 Data of environmental factors for each environment

Environment	X_1	X_2	X_3	X_4	X_5
City A, rural	15.2	70	1669	13.6	1.46
City B, marine	16.2	67	1400	16.7	12.05
City B, city	16.2	67	1400	16.7	5.55
City C, rural	14.9	71	1575	13.0	1.13
City D, marine	15.9	68	1393	15.5	8.63
City E, city	16.2	67	1400	17.2	5.55
City E, rural	15.2	70	1669	12.7	1.46
City F, mountainous	15.2	74	1199	11.0	0.18
City G, marine	22.4	77	2128	12.0	13.21

Note; X_1 : Temperature (°C)
X_2 : Humidity (%)
X_3 : Precipitation (mm/year)
X_4 : Sulfur-dioxide concentration (10^{-3}ppm)
X_5 : Sea-salt particles (10^{-4}g/cm^{2}year)

Table 4.9 Parameters for determining long-term corrosion of bare steel

Environment	Based on steel exposure test				Based on environmental factors			
	Expos. to rain		Under. bridges		Expos. to rain		Under. bridges	
	k	m	k	m	k	m	k	m
City A, rural	-	-	0.012	0.512	0.055	0.668	0.015	0.450
City B, marine	-	-	0.015	0.773	0.082	0.606	0.042	0.751
City B, city	-	-	-	-	0.079	0.614	0.025	0.616
City C, rural	0.068	0.314	0.015	0.735	0.051	0.621	0.013	0.470
City D, marine	-	-	-	-	0.074	0.601	0.033	0.717
City E, city	-	-	-	-	0.081	0.608	0.024	0.618
City E, rural	-	-	-	-	0.052	0.687	0.015	0.455
City F, mountainous	-	-	0.014	0.493	0.046	0.374	0.008	0.617
City G, marine	-	-	0.025	0.733	0.079	0.589	0.050	0.866

Note; $Y = k\ t^m$
Y : Corrosion depth (mm)
t : Exposure time (year)

Table 4.10 Corrosion ratio for rural and city environments

Condition	Part No.	Corrosion ratio a	σ_a	Number of data N
Exposed to rain	P1	1.408	0.820	51
	P2	0.470	0.195	58
	P4	0.466	0.165	57
	P6	0.526	0.185	38
	P8	0.623	0.226	65
	P14	0.558	0.102	2
	P15	0.424	0.164	53
	P17	0.449	0.146	53
	P19	0.505	0.236	24
	P21	0.537	0.200	65
Underneath bridge	P3	1.239	0.176	54
	P5	1.508	0.184	54
	P7	2.152	0.292	29
	P9	3.037	0.919	36
	P10	1.422	0.217	50
	P11	1.481	0.223	46
	P12	2.006	0.226	27
	P13	1.872	0.287	53
	P16	1.355	0.195	53
	P18	1.332	0.175	56
	P20	1.676	0.296	19
	P22	2.021	0.009	2
	P23	1.295	0.187	48
	P24	1.327	0.213	51
	P25	1.623	0.319	14
	P26	1.508	0.247	54

Note: Corrosion ratio of steel exposure test is 1.00.
Part Nos. refer to Fig. 3.4.

Table 4.11 Corrosion ratio for mountainous environments

Condition	Part No.	Corrosion ratio a	σ_a	Number of data N
Exposed to rain	P1	2.587	0.596	25
	P2	1.121	0.077	20
	P4	0.618	0.061	22
	P6	1.329	0.144	18
	P8	1.116	0.088	25
	P14	-	-	-
	P15	1.187	0.079	21
	P17	0.751	0.059	22
	P19	1.459	0.124	12
	P21	1.091	0.101	22
Underneath bridge	P3	2.547	0.061	20
	P5	3.009	0.059	22
	P7	3.081	0.171	30
	P9	9.521	0.685	14
	P10	2.619	0.048	18
	P11	2.086	0.056	16
	P12	3.281	0.158	11
	P13	1.975	0.063	19
	P16	2.044	0.061	19
	P18	2.363	0.056	21
	P20	3.846	0.118	7
	P22	-	-	-
	P23	3.118	0.057	17
	P24	3.157	0.061	16
	P25	-	-	-
	P26	2.072	0.050	17

Note: Corrosion ratio of steel exposure test is 1.00.
Part Nos. refer to Fig. 3.4.

Table 4.12 Corrosion ratio for marine environments

Condition	Part No.	Corrosion ratio a	σ_a	Number of data N
Exposed to rain	P1	1.496	0.709	38
	P2	0.547	0.185	42
	P4	0.476	0.170	39
	P6	0.670	0.010	7
	P8	0.707	0.235	46
	P14	-	-	-
	P15	0.490	0.146	36
	P17	0.415	0.167	39
	P19	0.980	0.006	7
	P21	0.770	0.458	45
Underneath bridge	P3	1.813	0.184	30
	P5	1.855	0.176	35
	P7	1.049	0.019	7
	P9	4.239	0.742	31
	P10	1.872	0.169	26
	P11	1.739	0.190	33
	P12	0.873	0.009	6
	P13	2.088	0.206	39
	P16	1.865	0.167	29
	P18	1.715	0.157	36
	P20	-	-	-
	P22	-	-	-
	P23	1.701	0.175	26
	P24	1.737	0.168	32
	P25	1.622	0.007	6
	P26	3.497	0.389	33

Note: Corrosion ratio of steel exposure test is 1.00.
Part Nos. refer to Fig. 3.4.

End part of span of main girders

	External girder	Internal girder
Shoe	1.41	3.04
Main girder	Outer side: 0.47, 0.47, 0.53 Inner side: 1.24, 1.51, 2.15 0.62	1.42, 1.48, 2.01 1.42, 1.48, 2.01 1.87

Middle part of span of main girders

	External girder	Internal girder
Main Girder	Outer side: 0.42, 0.45, 0.51 Inner side: 1.36, 1.33, 1.68 0.54	1.30, 1.33, 1.62 1.30, 1.33, 1.62 1.51
Expan. J.	0.56	2.02

Note ░░░ : Members exposed to rain

Fig. 4.12 Corrosion ratio for rural and city environments

End part of span of main girders

	External girder	Internal girder
Shoe	2.59	9.52
Main girder	0.12 2.55 Outer Inner side 0.62 3.01 side 1.33 3.08 1.12	2.62 2.62 2.09 2.09 3.28 3.28 1.98

Middle part of span of main girders

	External girder	Internal girder
Main Girder	1.19 2.04 Outer Inner side 0.75 2.36 side 1.46 3.85 1.09	3.12 3.12 3.16 3.16 - - 2.07
Expan. J.	-	-

Note ▒ : Members exposed to rain

Fig. 4.13 Corrosion ratio for mountainous environments

End part of span of main girders

	External girder	Internal girder
Shoe	1.50	4.24
Main girder	0.55 1.81 Outer Inner side 0.48 1.86 side 0.67 1.05 0.71	1.87 1.87 1.74 1.74 0.87 0.87 2.09

Middle part of span of main girders

	External girder	Internal girder
Main Girder	0.49 1.87 Outer Inner side 0.42 1.72 side 0.98 - 0.77	1.70 1.70 1.74 1.74 1.62 1.62 3.50
Expan. J.	-	-

Note ░░ : Members exposed to rain

Fig. 4.14 Corrosion ratio for marine environments

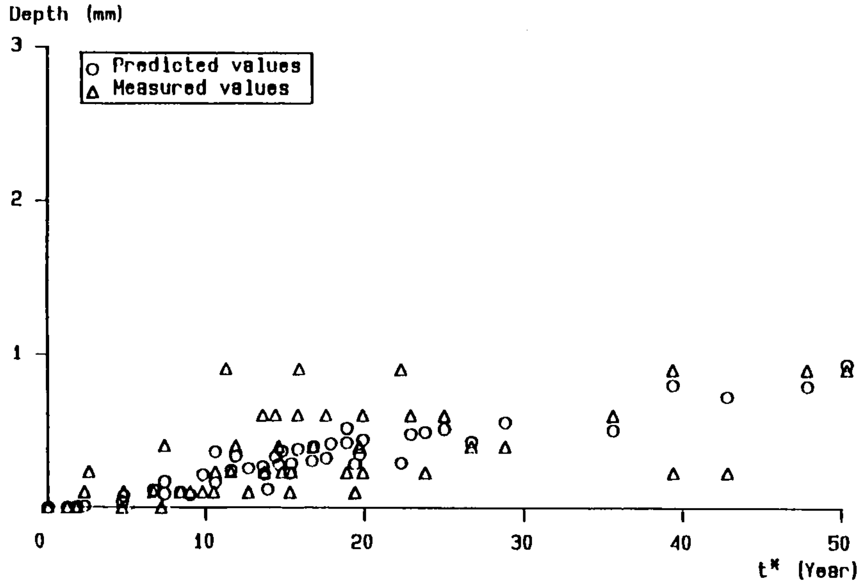


Fig. 4.15 Relation between corrosion depth and exposure time
P8 End part of span of main girder (External girder)
Lower surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

The corrosion process of bridge members is assumed to be the same for each cycle of paint. Total corrosion of bridge members is the sum of corrosion occurred in each cycle of paint. Consequently corrosion of normal painted steel materials is determined from the summation of corrosion occurring in each cycle of paint for each bridge by means of probabilistic analysis. Service life of paint for each bridge member is obtained from the results of the bridge survey in section 3.4. In this case, paint life obtained from Eq. 3.1 at RN 2 is used in the analysis. The distribution of paint life is assumed to be a log-normal distribution.

The results of corrosion of bridge members from surveying and the results of corrosion of steel materials determined from steel exposure test and paint life are applied to Eq. 4.8, and by the least-square method, corrosion ratio is obtained. The results of determined corrosion ratio for each environment and bridge member are shown in Table 4.10 to Table 4.12 and Fig. 4.12 to Fig. 4.14. From these results, corrosion of bridge members for each environment can be determined by the model in section 4.2 and Eq. 4.8. Fig. 4.15 shows one example of the results of the predicted corrosion depth of bridge members with the comparison of measured values from surveying for bridges in rural and city environments. The other results are shown in the appendix.

4.6 METHODS FOR DETERMINING THE EFFECT OF CORROSION DETERIORATION ON THE BRIDGE SAFETY

a) Effect of corrosion on the strength of bridge members

The process for evaluating the effect of corrosion on structural performance begins with estimating the amount of corrosion depth at a particular time. Both uniform and maximum (or local) corrosion depth can be determined using the models in the previous sections. Normally the effect of uniform corrosion on the strength of bridge members is not as serious as the effect of maximum (or local) corrosion. Therefore, only maximum (or local) corrosion is considered for determining the effect on the strength of bridge members.

Furthermore, the results of tension test of corroded steel materials showed that the weakest section of corroded materials is the section of smallest net remaining area.[27)] Consequently, in order to determine the effect of maximum (or local) corrosion on the strength of bridge members, average corrosion depth must be determined. This leads to the necessity of determining the relationship between maximum pit depth and average corrosion depth of the corroded members. Fig. 4.16 shows the plot of the data from the results of tension tests of corroded materials indicating the relationship between the maximum pit depth and the average corrosion depth. The relationship is assumed to be a linear equation passing through the origin. From these data, by the least square method, regression equation of average corrosion depth as a function of maximum pit depth is obtained as follows:

$$Y_{ave} = 0.760Y_{max} \tag{4.9}$$

where Y_{ave} represents average corrosion depth (mm). Y_{max} represents maximum pit depth (mm).

Moreover, the remaining capacity of the corroded material is normally less than the uncorroded material that has the same cross-sectional area. Therefore in order to determine the precise effect of corrosion on the strength of bridge members, effective corrosion depth, which is greater than average corrosion depth, must be determined. Effective corrosion depth is defined by the following equations:27)

$$Y_{eff} = (t_i - t_{eff})/2 \tag{4.10}$$

$$t_{eff} = P/WT \tag{4.11}$$

where t_i represents original plate thickness,
t_{eff} represents effective plate thickness,
P represents maximum load,
W represents width of the corroded steel plate,
T represents tensile strength of the uncorroded steel plate.

Fig. 4.17 shows the plot of the data from the results of tension tests of corroded materials indicating the relationship between average corrosion depth and effective corrosion depth. The relationship is assumed to be a linear equation passing through the origin. From these data, by the least square method, regression equation of effective corrosion depth as a function of average corrosion depth is obtained as follows:

$$Y_{eff} = 1.226Y_{ave} \tag{4.12}$$

where Y_{eff} represents effective corrosion depth (mm).

Based on the above results, the effect of corrosion on the strength of bridge members will be determined. In a steel girder, corrosion may affect the capacity in bending and shear. Bending will be considered mainly at the midspan of a girder for simple span girder bridges. Shear will be considered mainly at the end of span of a girder above the support. Fig. 4.18 illustrates the representative girder sections for determining the effect of corrosion on the bending and shear behavior. For steel girder bridges with a concrete deck plate, normally the upper surface of upper flange is embedded in the concrete deck plate. Therefore, corrosion of this portion will not occur. Corrosion depth for other parts of the section are determined based on the models in section 4.2, section 4.5, and the above two converting equations (Eq. 4.9 and Eq. 4.12). The representative environment for determining corrosion depth is the environment of city G (marine environment), who's environmental factors are shown in Table 4.8. Service life of paint is based on the service life of

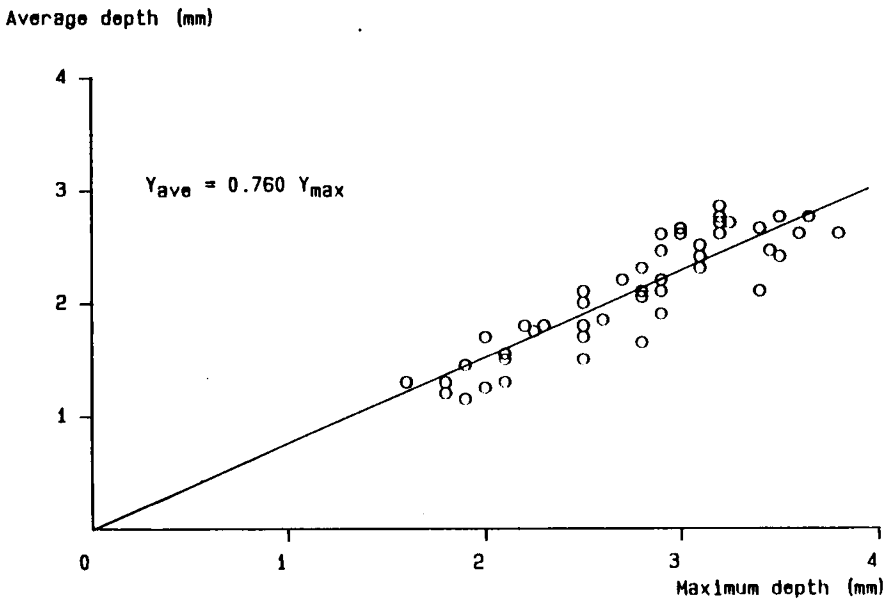


Fig. 4.16 Relation between average and maximum corrosion depth

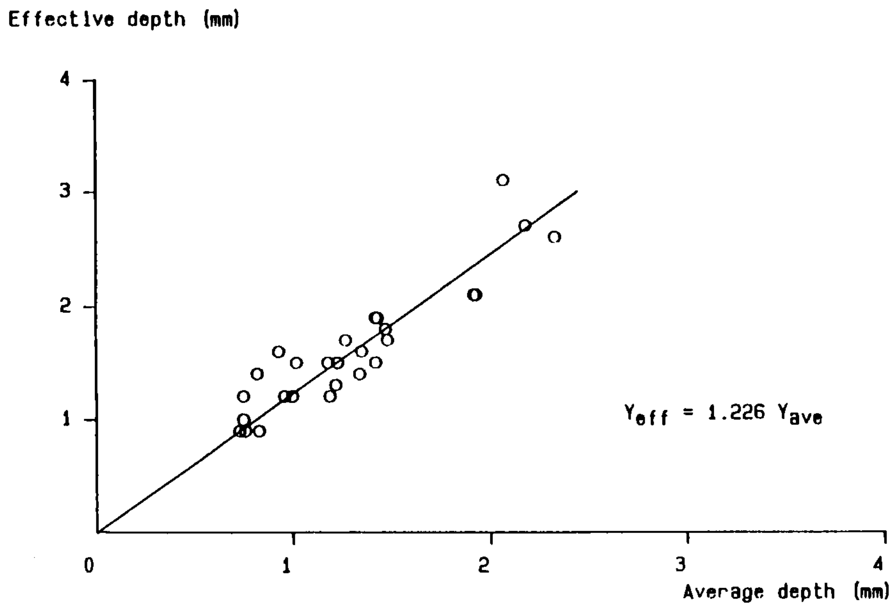


Fig. 4.17 Relation between effective and average corrosion depth

alkyd resin exposed to the environment of city G.

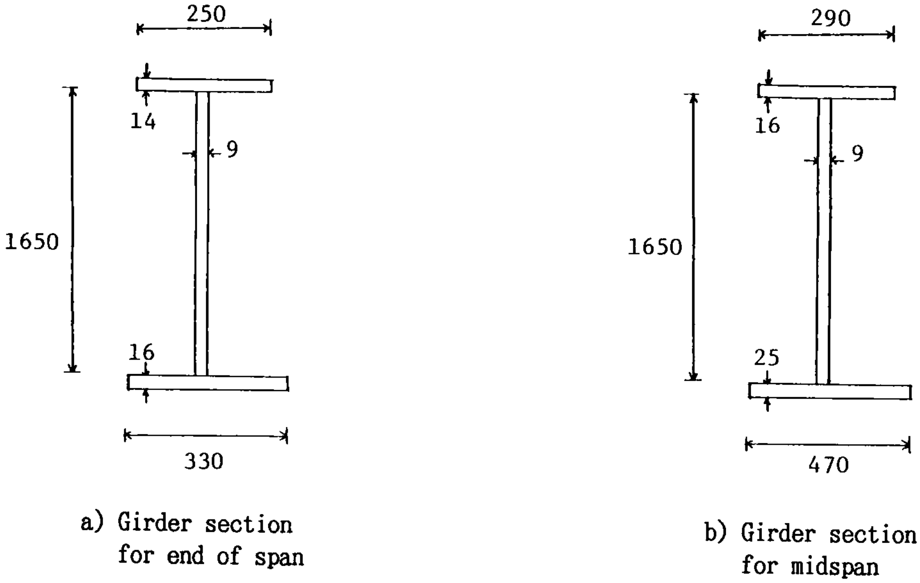


Fig. 4.18 Representative girder sections for determining the effect of corrosion on the bending and shear behavior

Bending behavior

The effect of corrosion on the bending behavior at the midspan of the girder for a simple span girder is determined in terms of bending stress ratio. This bending stress ratio is the ratio of bending stress of a corroded section to bending stress of an original uncorroded section. The bridge is assumed to resist the same amount of load before and after corroding. A basic assumption is made that plain sections before bending remain plain after bending. The result of the determined bending stress ratio is shown in Fig. 4.19. If the bending stress occurring in the bridge section is confined to the same level before and after corroding, the moment capacity of the section will decrease after corroding. Vertical axis in the right hand side of the Fig. 4.19 shows the percent remaining moment capacity of the section after corroding.

Shear behavior

The effect of corrosion on the shear behavior at the end of the span of a girder is determined in terms of shear stress ratio. Shear stress ratio is the ratio of shear stress of a corroded section to shear stress of an original uncorroded section. The bridge is also assumed to resist the same amount of load before and after corroding. The result of the determined shear stress ratio is shown in Fig. 4.20. Vertical axis in the right hand side of this figure shows the percent of shear capacity remaining in the section after

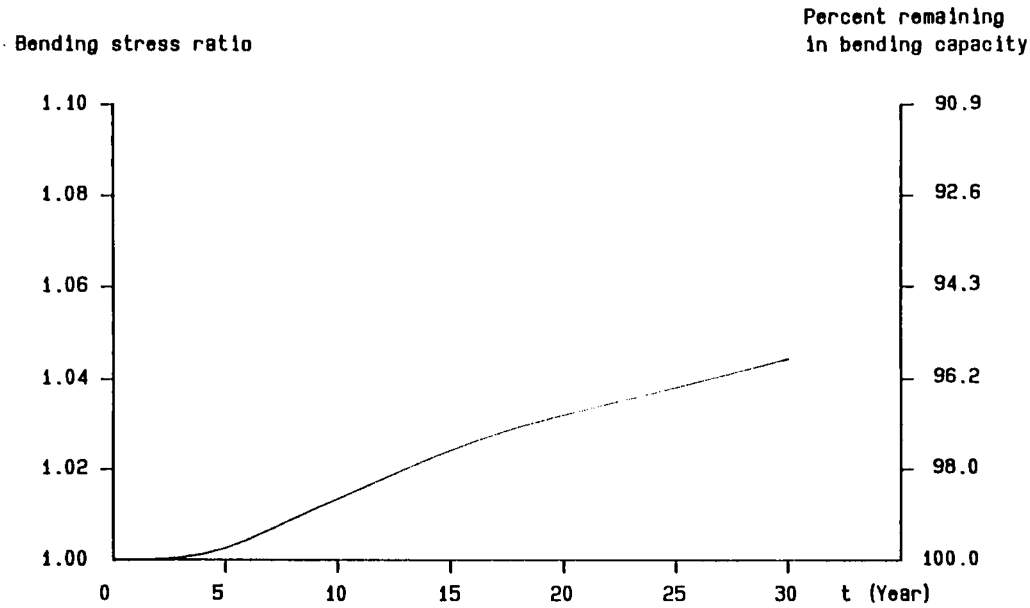


Fig. 4.19A Bending behavior for midspan of girder of external girder
City G, Marine environment, Paint type = alkyd resin

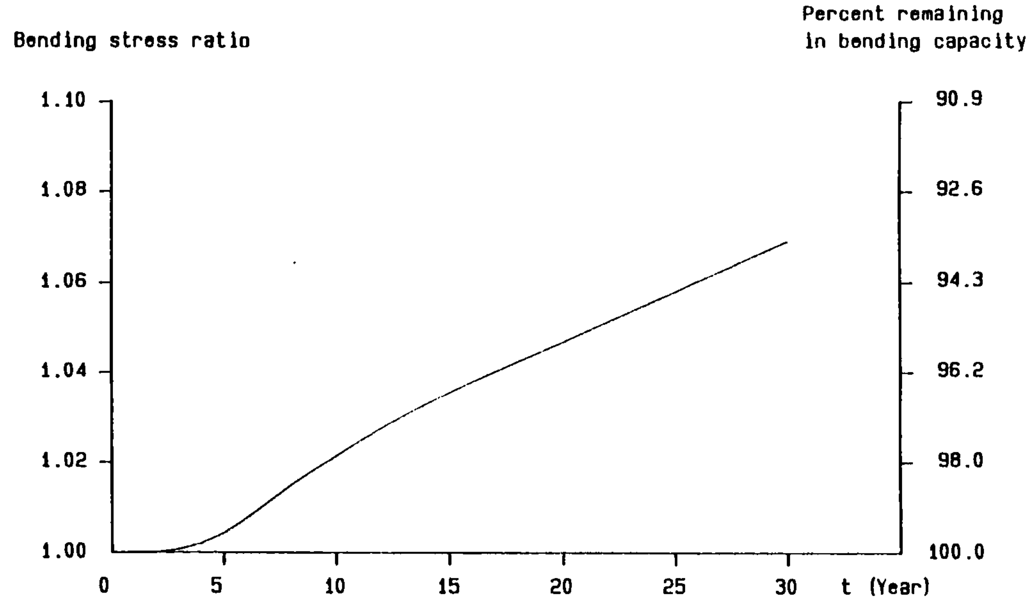


Fig. 4.19B Bending behavior for midspan of girder of internal girder
City G, Marine environment, Paint type = alkyd resin

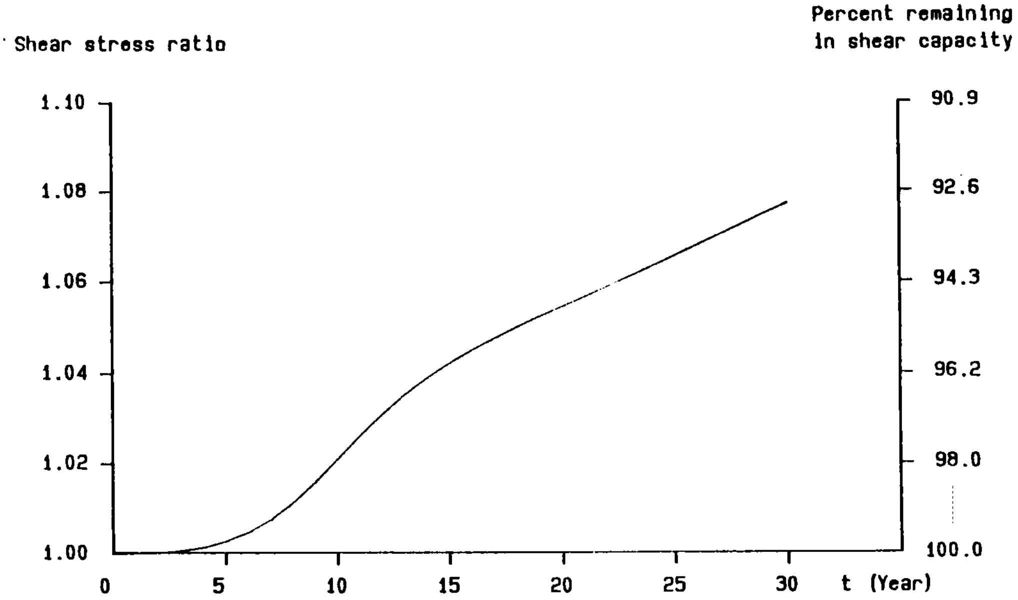


Fig. 4.20A Shear behavior for end of span of girder of external girder City G, Marine environment, Paint type = alkyd resin

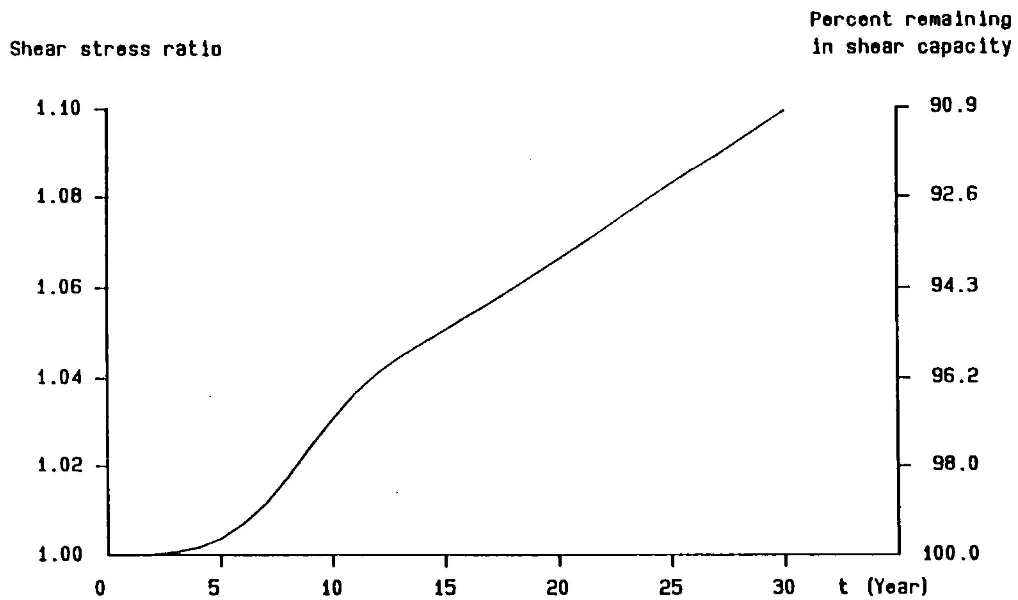


Fig. 4.20B Shear behavior for end of span of girder of internal girder City G, Marine environment, Paint type = alkyd resin

corroding if the shear stress occurring in the bridge section is confined to be the same level before and after corroding.

b) Methods for determining the safety of existing bridges

As mentioned before, there are a large number of bridges built of steel. Many of these bridges are undergoing deterioration due to corrosion. The need has arisen to determine the safety of these existing bridges. The evaluation of these existing bridges is difficult when considering all the uncertainties involved in deterioration. The safety of existing bridges due to corrosion deterioration is determined in terms of deteriorating index. Two methods for determining the safety of existing bridges are developed based on the field data of corrosion deterioration of bridge members. Method one is to evaluate the global deterioration of the bridge. Method two is to evaluate the local deterioration of the bridge.

Overall deterioration

Data of steel corrosion for 26 different parts (refer to Fig. 3.4) of a bridge are collected from surveying by means of rating number of steel corrosion. Among these 26 different bridge members, the number of bridge members of normal areas (exclude water leaky areas) for each rating number (A - G') is counted and substitute into the following equation:

$$Z1 = \frac{0(n_A)+0.1(n_B)+0.23(n_C)+0.4(n_D)+0.6(n_E)+0.9(n_F)+3(n_G)+10(n_{G'})}{n_A+n_B+n_C+n_D+n_E+n_F+n_G+n_{G'}} \qquad (4.13)$$

where $Z1$: Overall deteriorating index
n_A : Number of rating number A of normal areas
n_B : Number of rating number B of normal areas
n_C : Number of rating number C of normal areas
n_D : Number of rating number D of normal areas
n_E : Number of rating number E of normal areas
n_F : Number of rating number F of normal areas
n_G : Number of rating number G of normal areas
$n_{G'}$: Number of rating number G'of normal areas

Local deterioration

Among 26 different bridge members, the number of bridge members of both normal areas and water leaky areas for rating number of F, G, and G'is counted and substitute into the following equation:

$$Z2 = 1(FF) + 3(GG) + 10(HH) \qquad (4.14)$$

where Z2 : Local deteriorating index
FF : Number of rating number F of both normal and water leaky areas
GG : Number of rating number G of both normal and water leaky areas

HH : Number of rating number G'of both normal and water leaky areas

Based on the above two methods, the deteriorating index Z1 and Z2 are determined for 247 existing bridges based on the data of steel deterioration from surveying. The results are shown in Table 4.13.

Criteria for judgment of bridge safety

Overall deterioration

Class	Criterion	Judgment
S1	$Z1 \geq 1.1$	very severe damage, very deficient bridge
S2	$0.7 \leq Z1 < 1.1$	severe damage, deficient bridge
S3	$0.4 \leq Z1 < 0.7$	significant damage, may develop to class S2,
S4	$0.1 \leq Z1 < 0.4$	small damage, no significant effect on bridge safety
S5	$Z1 < 0.1$	safety

Note: A deficient bridge is not necessary an unsafe bridge. But it has the possibility to be unsafe.

Local deterioration

Class	Criterion	Judgment
S1	$Z2 \geq 100$	very severe damage, very deficient bridge
S2	$25 \leq Z2 < 100$	severe damage, deficient bridge
S3	$10 \leq Z2 < 25$	significant damage, may develop to class S2,
S4	$3 \leq Z2 < 10$	small damage, no significant effect on bridge safety
S5	$Z2 < 3$	safety

Note: A deficient bridge is not necessary an unsafe bridge. But it has the possibility to be unsafe.

Class S1:

Overall deteriorating index Z1 and local deteriorating index Z2 of bridge No. A-6 are 1.146 and 102 respectively (see Table 4.13). This bridge has very severe damage due to corrosion throughout the bridge. It was considered that this bridge may be unsafe for public use, and has been replaced with a new one. Based on this bridge, bridges of which overall deteriorating index Z1 is greater than or equal to 1.1 are considered as very deficient bridges. Bridges of which local deteriorating index Z2 is greater than or equal to 100 are also classified as very deficient bridge.

Class S2:

Severe damage and a deficient bridge is classified for bridges that have overall deteriorating index Z1 greater than or equal to 0.7. This means that local corrosion occurs all over the bridge. Because the rate of local corrosion is high in nature, the bridge has a possibility to be unsafe. The value of 0.7 overall deteriorating index Z1 is correspondent to the value of about 25 local deteriorating index Z2.

Class S3:

Significant damage is classified for bridges of which overall deteriorating index Z1 is greater than or equal to 0.4, but still lower than 0.7. It means that the average stage of steel corrosion is approximately RN D or RN E throughout the bridge. For local deteriorating index, it is considered that even if there is only one bridge member, if the stage of steel corrosion is RN G', the bridge has significant damage. Therefore the lower boundary of Z2 for class S2 is 10.

Class S4:

Small damage is classified for bridges of which overall deteriorating index Z1 is greater than or equal to 0.1, but still lower than 0.4. The average stage of steel corrosion is approximately RN B or RN C. There is corrosion damage in bridge members, but there is not significant effect on bridge safety due to corrosion deterioration. For local deterioration, small damage is considered when local deteriorating index Z2 is greater than or equal to 3, but still lower than 10.

Class S5:

Bridges will be considered safe when overall deteriorating index Z1 is lower than 0.1 and local deteriorating index Z2 is lower than 3. There is no bridge member of which the stage of steel corrosion is RN G or RN G'. Not more than two bridge members of which the stage of steel corrosion may be RN F, and the average stage of steel corrosion over the bridge is less than RN B.

Table 4.14 summarized the number of cases in each city that fall into each class of bridge deterioration based on the above classifications.

Table 4.13 Results of the determined deteriorating index of surveyed bridges

Order of Z1	Bridge No.	Deterio. index Z1	Z2
1	A-6	1.146	102
2	B-11	1.086	29
3	B-24	1.042	52
4	B-87	0.900	40
4	B-58	0.900	96
6	A-10	0.880	42
7	A-30	0.872	23
8	A-1	0.830	76
9	B-26	0.710	8
10	B-66	0.705	7
11	A-23	0.700	20
12	B-19	0.675	6
13	A-7	0.660	13
14	B-15	0.613	6
15	B-47	0.608	6
16	B-67	0.566	2
17	A-22	0.527	6
18	B-12	0.511	7
19	B-2	0.505	3
20	B-81	0.504	23
21	F-32	0.501	3
22	B-63	0.489	22
23	B-52	0.480	6
24	A-3	0.475	10
25	B-3	0.463	6
26	A-19	0.444	11
27	A-33	0.432	7
28	B-85	0.424	16
29	A-32	0.415	25
30	B-74	0.401	59
31	B-64	0.386	0
32	E-14	0.382	0
33	B-20	0.378	2
34	B-37	0.375	23
35	B-88	0.370	5
36	F-14	0.368	2
37	B-36	0.360	0
38	B-76	0.355	11
39	B-35	0.351	0
40	B-42	0.346	0
41	B-68	0.337	6
41	B-40	0.337	3
43	B-4	0.333	0
44	B-13	0.327	4
45	B-23	0.326	0
46	C-4	0.319	4
47	B-50	0.305	0
48	B-45	0.301	0
49	B-72	0.291	13
50	B-51	0.289	1

Order of Z1	Bridge No.	Deterio. index Z1	Z2
51	B-1	0.276	0
52	G-17	0.273	4
52	B-78	0.273	3
54	B-84	0.272	2
55	B-82	0.265	1
56	A-16	0.257	6
57	B-73	0.255	61
58	G-7	0.247	4
59	B-70	0.244	0
60	B-75	0.242	4
61	B-71	0.231	9
62	B-59	0.230	6
62	B-44	0.230	0
64	A-35	0.223	1
65	A-4	0.219	1
66	B-48	0.215	0
67	B-46	0.213	0
68	B-49	0.205	6
69	F-2	0.201	9
70	B-56	0.200	0
71	F-5	0.196	3
72	E-34	0.189	0
73	F-36	0.188	2
74	C-14	0.182	1
75	B-53	0.180	0
76	E-52	0.176	1
76	B-22	0.176	0
78	D-15	0.173	0
79	B-43	0.171	0
79	B-69	0.171	0
81	A-24	0.170	0
82	C-17	0.168	2
83	G-18	0.161	2
84	G-8	0.158	1
85	A-9	0.155	0
86	A-13	0.153	0
87	D-14	0.149	0
88	B-27	0.148	0
89	A-14	0.146	21
89	G-2	0.146	5
89	G-9	0.146	1
89	D-12	0.146	0
93	B-86	0.144	0
94	A-8	0.142	80
94	E-11	0.142	1
96	A-39	0.140	2
97	B-41	0.138	0
98	D-13	0.128	0
99	E-8	0.126	1
100	A-34	0.120	1

Table 4.13 Continue.

Order of Z1	Bridge No.	Deterio. index Z1	Z2
101	A-20	0.115	0
102	F-17	0.114	0
103	C-18	0.107	0
104	B-89	0.105	11
104	E-51	0.105	0
104	D-16	0.105	0
107	E-27	0.101	0
108	A-41	0.100	60
108	F-1	0.100	4
108	E-23	0.100	0
111	F-33	0.099	1
112	F-6	0.094	6
113	C-21	0.093	0
114	E-1	0.087	0
114	E-17	0.087	0
114	E-26	0.087	0
117	F-31	0.086	0
118	B-80	0.084	1
119	B-83	0.083	5
119	G-23	0.083	4
121	D-8	0.082	3
122	F-21	0.080	1
122	E-7	0.080	0
124	E-42	0.078	0
124	E-44	0.078	0
126	C-8	0.077	7
127	D-11	0.076	0
128	B-21	0.075	2
129	A-28	0.072	3
130	C-20	0.070	0
131	A-37	0.066	0
132	F-9	0.059	38
133	E-27	0.058	0
134	G-28	0.057	0
135	C-12	0.055	0
135	C-13	0.055	0
137	C-23	0.054	0
138	E-48	0.052	1
138	E-49	0.052	0
140	E-41	0.050	0
141	G-25	0.047	2
141	F-25	0.047	1
143	E-20	0.046	0
143	C-22	0.046	0
145	F-23	0.045	20
145	A-12	0.045	1
147	A-38	0.043	0
148	F-29	0.042	4
148	E-46	0.042	0
150	D-1	0.041	1
150	E-25	0.041	0
152	A-5	0.039	7
152	F-12	0.039	1
153	G-20	0.038	1
154	E-35	0.037	0
154	A-2	0.037	0
156	A-29	0.036	0
157	C-10	0.034	0
158	F-26	0.033	2
158	D-9	0.033	0
160	F-7	0.032	6
161	E-6	0.027	0
162	G-4	0.026	4
163	C-24	0.025	0
164	D-7	0.022	3
164	C-9	0.022	0
164	E-40	0.022	0
164	D-4	0.022	0
164	G-3	0.022	0
169	D-6	0.020	0
170	G-24	0.018	2
170	E-24	0.018	0
170	F-20	0.018	0
170	G-16	0.018	0
174	A-42	0.017	1
175	D-3	0.016	0
176	F-4	0.015	6
177	E-2	0.014	0
178	F-16	0.013	1
179	F-3	0.011	4
179	F-22	0.011	0
181	A-21	0.010	14
182	E-47	0.009	0
183	G-27	0.008	1
184	A-11	0.006	0
184	D-5	0.006	0
184	D-10	0.006	0
184	G-11	0.006	0
188	B-38	0.005	0
189	F-34	0.004	1
189	A-15	0.004	0
189	F-27	0.004	0
192	C-7	0.003	0
193	B-57	0.000	24
193	A-25	0.000	12
193	A-18	0.000	8
193	A-27	0.000	6
193	C-2	0.000	6
193	F-8	0.000	3
193	A-26	0.000	2

Table 4.13 Continue.

Order of Z1	Bridge No.	Deterio. index Z1	Z2
193	F-24	0.000	2
193	F-30	0.000	2
193	B-79	0.000	1
193	E-10	0.000	1
193	F-13	0.000	1
193	F-15	0.000	1
193	G-12	0.000	1
193	G-13	0.000	1
193	G-14	0.000	1
193	A-17	0.000	0
193	A-31	0.000	0
193	A-36	0.000	0
193	A-40	0.000	0
193	B-5	0.000	0
193	B-16	0.000	0
193	B-18	0.000	0
193	B-25	0.000	0
193	B-34	0.000	0
193	B-39	0.000	0
193	B-65	0.000	0
193	C-1	0.000	0
193	C-3	0.000	0
193	C-5	0.000	0
193	C-6	0.000	0

Order of Z1	Bridge No.	Deterio. index Z1	Z2
193	C-11	0.000	0
193	C-15	0.000	0
193	C-16	0.000	0
193	C-19	0.000	0
193	D-2	0.000	0
193	E-9	0.000	0
193	E-16	0.000	0
193	E-18	0.000	0
193	E-32	0.000	0
193	E-53	0.000	0
193	F-10	0.000	0
193	F-11	0.000	0
193	F-18	0.000	0
193	F-19	0.000	0
193	F-28	0.000	0
193	G-1	0.000	0
193	G-5	0.000	0
193	G-6	0.000	0
193	G-10	0.000	0
193	G-15	0.000	0
193	G-19	0.000	0
193	G-21	0.000	0
193	G-22	0.000	0
193	G-26	0.000	0

Table 4.14 Summary of the number of cases of bridges in each class of bridge deterioration.

City	Class S1			Class S2			Class S3			Class S4			Class S5			Total
	Z1	Z2	sum	Z1	Z2	sum	Z1	Z2	sum	Z1	Z2	sum	Z1	Z2	sum	
A	1	1	2 2.4%	4	5	9 10.7%	6	8	14 16.7%	12	8	20 23.8%	19	20	39 46.4%	84 100%
B	0	0	0 0%	6	6	12 8.6%	12	8	20 14.3%	39	19	58 41.4%	13	37	50 35.7%	140 100%
C	0	0	0 0%	0	0	0 0%	0	0	0 0%	4	3	7 14.6%	20	21	41 85.4%	48 100%
D	0	0	0 0%	0	0	0 0%	0	0	0 0%	5	2	7 21.9%	11	14	25 78.1%	32 100%
E	0	0	0 0%	0	0	0 0%	0	0	0 0%	8	0	8 12.1%	25	33	58 87.9%	66 100%
F	0	0	0 0%	0	1	1 1.5%	1	1	2 2.9%	6	10	16 23.5%	27	22	49 72.1%	68 100%
G_1	0	0	0 0%	0	0	0 0%	0	0	0 0%	6	4	10 12.5%	14	16	30 37.5%	40 100%
G_2	0	0	0 0%	0	0	0 0%	0	0	0 0%	0	1	1 6.3%	8	7	15 93.8%	16 100%

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5 PROTECTION OF STEEL BRIDGES AGAINST CORROSION[1)-5)]

5.1 INTRODUCTION

Protection of structural steelwork against corrosion has become an important topic among engineers and researches since it was found that corrosion can be the cause of the structural failure. For structural steel bridges, one example of bridge failures due to corrosion is the failure of Clapham Junction Bridge in 1965.[6)] Another example of bridge failure is the collapse of the well-known Point Pleasant Bridge in 1967, an accident in which 46 persons were killed. The main cause of the collapse is considered to be stress corrosion crack in the eyebar head.[7)-11)]

As the number of steel bridges increases gradually nowadays, the methods for protecting these bridges against corrosion must be considered. Protection of bridges against corrosion can be performed at the beginning stage of structural design. The possibility of bridge maintenance and inspection against corrosion after construction should be taken into consideration. However, an adequate consideration on this matter can be achieved only when the designer has sufficient experience.[12)] After completion of the bridges, protection of steel bridges against corrosion involves mainly bridge maintenance and inspection. With good design of bridges and adequate maintenance and inspection, a long service life of bridges can be expected.

5.2 DESIGN CONSIDERATION

Corrosion protection of structures begins at the design desk. Adequate maintenance and inspection can be achieved only in the case of good design. Good design should performed in order that all of the bridge members can be reached and inspected. An example of bad design is the collapse of the Point Pleasant Bridge. The location of the corroded eyebar, which is the main cause of failure, was in the position that could not be inspected.[11)] This eyebar was corroded for a long time, but this defect could not found out even an in-depth inspection at every two years was performed.

The other point of good design is to design the bridge members so they are not prone to corrosion. Certain problems that will be the cause of corrosion should be avoided. Total exposed surfaces of steel should be easily accessible for painting and maintenance. Extra protection should be provided to parts or areas which are inaccessible. For example, metallic coatings, additional painting or both should be provided. The other general considerations are to design the structures so as not allow water-traps and to design in order that wind can circulate throughout the structures.

An overview of design consideration

1) Bearings

Bearing is the most corrosive part of the superstructures. The main cause of corrosion is the accumulation of dirt, sand, and other debris that pass through the joint between approach and bridge deck. Combined with water coming through the joint, the debris forms an atmosphere conducive to corrosion.

One of the design consideration in reducing the corrosion problem at bearings is to use undrained joint between approach and bridge deck to prevent water, dirt, sand, and other debris pass through the joint. The level of bearings over the abutment should be high enough to prevent the accumulation of dirt and debris on bearings. Grade at abutment should be provided in order to prevent water-traps (see Fig. 5.1). Metallic coatings or additional painting or both should be provided. Rubber bearing is one of the other considerations to prevent corrosion problem at bearings.[13)]

2) Beams or stringers

Beams or stringers face with the problems of dirt and debris that accumulated on the flange and water-traps due to rain and condensation. It is good recommended that the grade at flange after completion should be at least two degree (Fig. 5.2).[14)-17)] Sharp edges and corners should be avoided. It is recommended that structures with rounded angles should be used where possible (Fig. 5.3).[18),19)] The width of the flange should be the same along the span. If it is necessary to reduce the section of flange, reduction in thickness is better than reduction in width of the flange.[20)] Steelwork should be designed with the view of avoiding entrapment of moisture and dirt, and should be designed in order that wind can circulate throughout the structures.[21)]

3) Decks

Leaking deck is the major problem of severe corrosion of steelworks. Because both chloride-laden on bridge deck and chloride contamination in concrete deck can pass with water through the leaking deck and penetrate on the structures. Chlorides are a major contributor to the accelerated corrosion of steel members.[22)-24)]

One of the essential points to prevent leaking deck is to use non-permeable deck.[25),26)] The other point is to design a good drainage pavement. Free water that easily enters and collects within undrained pavement is a primary cause of premature and continuing damage. Grade at bridge should be provided in order to drain free water out of pavement. Fig. 5.4 shows the good and poor practice of the grade at bridge.[27)]

4) Deck expansion joints

Expansion joints are a major cause of problems in all types of structures.

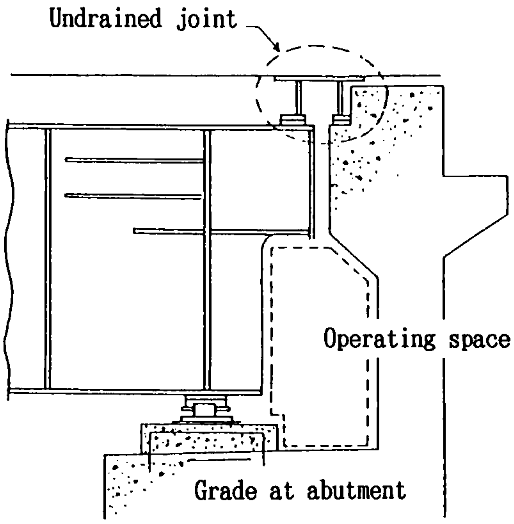


Fig. 5.1 Undrained joint between approach and bridge deck and grade at abutment should be provided.[17]

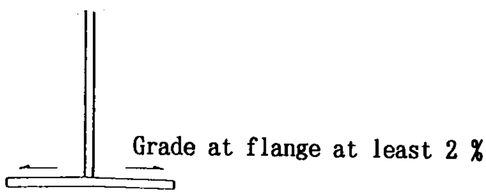


Fig. 5.2 Grade at flange to prevent water-traps[14)-17]

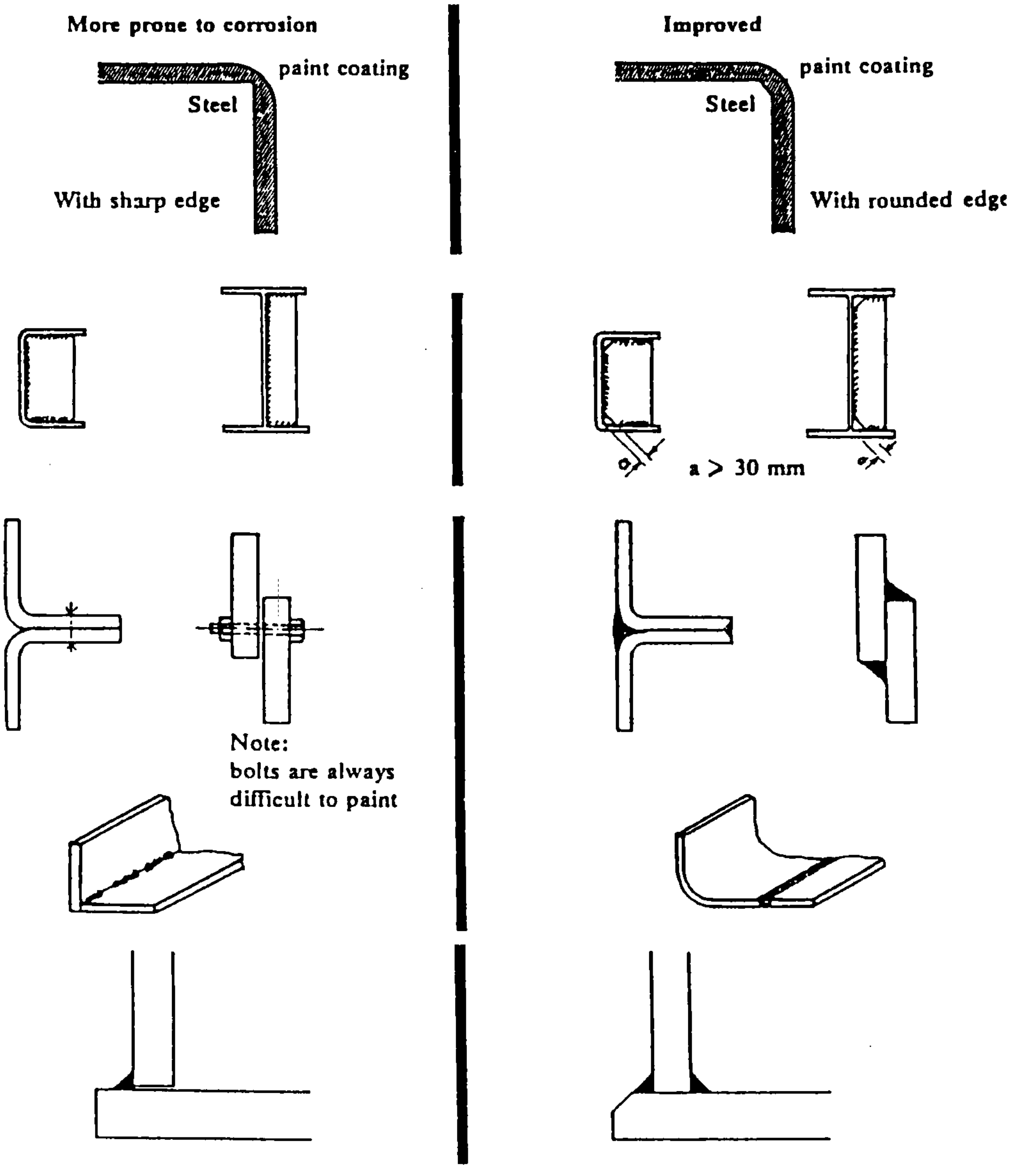
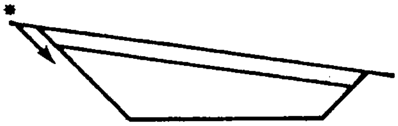
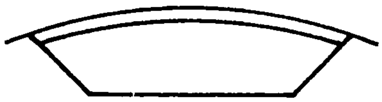
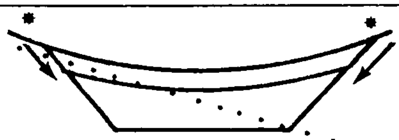
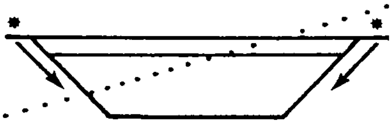


Fig. 5.3 Structures with rounded angles to avoid corrosion. Edges and corners are corrosion sensitive points even when protected by coating.[18),19)]

POOR PRACTICE

CASE	GRADE AT BRIDGE	RURAL PAVING (NO CURBS ON APPROACH PAVEMENT)	URBAN PAVING (CURBS ON APPROACH PAVEMENT)
A	 ONE AND HIGHER THAN THE OTHER	USE CATCH BASINS AT LOW END ONLY	USE CATCH BASINS AT BOTH SIDES
B	 BOTH ENDS LOWER THAN CENTER	USE CATCH BASINS AT BOTH ENDS	USE CATCH BASINS AT BOTH ENDS
C	 BOTH ENDS HIGHER THAN CENTER	USE NO CATCH BASINS. USE DRAINS ON BRIDGE DECK	USE CATCH BASINS AT BOTH ENDS AND DRAINS ON BRIDGE DECK
D *	 FLAT GRADE	USE CATCH BASINS AT BOTH ENDS ONLY WHEN NO DRAINS ARE USED ON BRIDGE DECK	USE CATCH BASINS AT BOTH ENDS

* Note: Positive bridge-end drainage is required.

Fig. 5.4 Grade at bridge deck to prevent water-traps[27)]

Leaking expansion joint pose a particular hazard for steel structure, since they permit chloride-laden run-off direct access to the superstructure elements. In addition to chloride, dirt, sand, and other debris pass through leaking expansion joints. These materials accumulate on the flange of superstructure members as well as on and around the bearings. Combined with moisture coming through the joints, the environment becomes tremendously corrosive to the steel.

Building jointless bridges, using undrained expansion joints, and simplifying expansion joint details are three identified measures for consideration in reducing the corrosion problem at expansion joints.[28),29)]

5) Drainage holes

Many drainage holes have been detailed on bridge plans with little regard to their design or effectiveness. If the drainage holes are not put in an appropriate place, water spray from drainage holes can make a serious problem of corrosion deterioration.

The main point is not to design drainage holes in the same vertical direction over any bridge members. Pipe should be used at drainage holes to prevent water spray. The level of the opened end of pipe should be lower than any members of superstructure. Pipe should be made from un-corrodible materials such as plastic.

5.3 BRIDGE MAINTENANCE AND INSPECTION AGAINST CORROSION

The essential reason for performing proper bridge maintenance is to insure safety for public use of bridges. Several levels of bridge maintenance can be performed. In general, bridge maintenance involves cleaning, protecting and performing relatively minor repairs to a bridge before deterioration becomes so extensive that rehabilitation or replacement is required. Inspections should not only be confined to searching for defects that may already exist, but also should seek potential problems that require preventive action. Inspections are valuable not only for evaluating maintenance activities, but also for providing resource data for planning, and design. These data are necessary for improving the future overall condition of bridges.

An effective maintenance management system should operate with as many regularly scheduled maintenance activities as possible. For greatest efficiency, the optimum between the performance of regularly scheduled activities must be known for each bridge, which requires inspections at regular intervals to evaluate and adjust the schedule. In general, maintenance inspections should be conducted about every six months. Every fourth inspection should include an in-depth safety inspection, which requires a thorough hands-on evaluation and considerably more time than the usual inspection.

a) An overview of inspection[30)-35)]

1) Bearings

All bearing devices, both fixed and expansion, should be examined carefully to make certain they are functioning properly. Inexplicable changes in the bearing can indicate serious problems in other parts of the structure, such as pier or abutment movement. Expansion bearings should be checked to make sure they allow proper movement. If a bearing is frozen because of corrosion or debris, expansion-contraction forces from the superstructure can damage other parts of the structure.

Dirt or debris that has accumulated around bearings causes metal bearing assemblies to corrode and become frozen. Problems in elastomeric bearing are evidenced by bulging, splitting, or tearing of the material. Roller-type bearings should also be checked to make sure that they are functioning properly and are free from corrosion and debris, which inhibit their movement.

2) Beams or stringers

Beams or stringers can be fabricated of timber, steel, or concrete. Each presents specific maintenance problems. Problems commonly found in steel beams or stringers are: dirt on the flanges; rust below the expansion joints; rust on the beam caused by moisture allowed through cracks in the deck; paint deterioration such as peeling, blistering, or cracking; loose connections; cracking or corrosion around rivet and bolt heads; and cracks in the welds. Steel beams should be checked to make sure that they are supported properly, exhibit no unusual twisting or seep, and that the beam has not been damaged either by collision or corrosion.

3) Decks

Deck inspection should including monitoring of deck drains to maintain proper drainage and eliminate areas where water can pond. Depressions or ruts that retain water, particularly if they are of any appreciable size, can contribute to hydroplaning. Drains and scuppers should be kept open and the deck clear of debris, since poor deck drainage and debris accumulation accelerate surface deterioration.

Concrete decks should be examined for cracking, leaching, scaling, potholing, spalling, and other evidence of deterioration. Any evidence of deterioration of the reinforcing steel should be inspected closely to determine its extent. Concrete deck problems are particularly severe in locations where deicing salts are used, although similar problems occur in warm coastal areas. Salt penetrates the concrete and corrodes the reinforcing steel, causing severe spalling and damage.

Steel decks should be inspected for corrosion, broken bars, and unsound welds. The inspector should note other typical problems found in steel decks: dirt collected in open grid decking on the top of the stringers, deteriorated paint, and loose connections where the deck is fastened to the stringers. Steel decks should also be checked for excessive looseness and noise under traffic.

4) Deck Expansion Joints

A space is usually provided between two superstructure spans, or between superstructure spans and abutments, to accommodate horizontal movement and rotation. The discontinuity created by this opening can cause roughness on the roadway surface and often becomes a conduit through which moisture and foreign materials are deposited on the supporting elements beneath the deck surface. Several problems associated with these deck joints should be checked during inspection. Joints often have metal plates that serve as an armor around the joint, and sometimes as a sliding surface to cover the joint.

A flexible material in the joint, such as a compression seal, prohibits the passage of moisture and debris and protects the areas below the deck. The inspector should examine seals to ensure they are in place and functioning properly. Debris and noncompressibles in the joint can damage the joint seal, and raveling edges of the joint will render the seal ineffective. If the joint is overlaid with an asphalt wearing surface, the seal cannot be inspected or maintained. Deck expansion joints normally require regular maintenance and inspection; if neglected, they can result in costly on the supporting members of the bridge.

5) Wearing surfaces

Asphalt or other types of wearing surfaces on a bridge deck can conceal serious defects. The surface must be examined carefully for evidence of deterioration, such as cracking, surface break-up or excessive deflection. Hollow sounds, produced by a chain drag passing over the surface, are a sign of delamination between the wearing and deck surfaces. This delamination is often the result of the deterioration of the top surface of the deck which, in turn, is caused by moisture passing through the porous wearing surface. Asphalt wearing surfaces are not waterproof unless a waterproofing membrane has been first applied to the top of the concrete deck.

6) Approaches

Approaches should be level and on-grade with the bridge. If the transition between the approach and the structure is not smooth and even, impact loads of substantial size can cause extensive, serious structural damage over a period of time. The approach pavement adjacent to the bridge should be checked with a straight-edge for unevenness, settlement, or roughness. Cracking or settlement in an approach may indicate a void under the pavement caused by fill settlement or scour around the abutment. When structures have concrete pavement approaches, it is important to cut relief joints in the concrete to prevent pressure being placed on the structure from pavement creep. The shoulders, slopes, ditches, and approach guardrail should also be evaluated during the inspection.

b) Model for determining the efficiency of maintenance system

A simple model for determining the efficiency of maintenance systems was developed in this research. A questionnaire of bridge maintenance and inspection was sent to 28 administrations that have steel bridges in supervision. The results of the questionnaire were used for determining the efficiency of maintenance systems. The details of this questionnaire are as follows:

QUESTIONNAIRE OF BRIDGE MAINTENANCE AND INSPECTION

Bridge Engineering Laboratory
Kyoto University

(1) How many bridges (steel bridges) are under your supervision ?

1. < 50 2. 50-100 3. 101-200 4. 201-300
5. 301-400 6. 401-500 7. > 500

(2) How long is the expected service life of your bridges (plate girder bridges) ?

1. < 20 years 2. 20-40 years 3. 41-60 years 4. 61-80 years
5. 81-100 years 6. 101-150 years 7. 151-200 years 8. > 200 years

(3) What types of paint do you often use ?

[1] Alkyd resins [2] Chlorinated rubber [3] Expoxy resins
[4] Polyurethane resins [5] Tar-expoxy resins [6] Other (   )

Give the three most often used paint types (orderly from the most often used one)

1. (   ) 2. (   ) 3. (   )

(4) How long is the paint cycle for each type of paint you selected in (3) ?

[1] < 3 years [2] 3-5 years [3] 6-8 years [4] 9-11 years
[5] 12-14 years [6] 15-17 years [7] 18-20 years [8] > 20 years

1. (   ) 2. (   ) 3. (   )

(5) What type of surface preparation do you use before repainting ?

1. Type 1 2. Type 2 3. Type 3 4. Type 4

Type 1 : white metal: complete removal of rust, mill scale, and paint residues.

Type 2 : commercial: complete removal of rust, paint residues or other materials except tightly bounded residues. The surface quality obtained may be non uniform as cleanliness or appearance are concerned.

Type 3 : power tool cleaning: removal of all rust and mill free scale. Mill scale tightly bounded rust and paint layer are yet left on the surface.

Type 4 : hand tool cleaning: removal of loose rust and dirt. Active paint layer are still left on the surface.

(6) How long is the cycle for general inspection ?

1. everyday	2. 7 days	3. 15 days	4. 1 month
5. 2-3 months	6. 6 months	7. 1 year	8. 2-3 years
9. 4-5 years	10. > 5 years	11. no general inspection	

(7) How long is the cycle for in-depth inspection ?

1. 15 days	2. 1 month	3. 2-3 months	4. 6 months
5. 1 year	6. 2-3 years	7. 4-5 years	8. 6-10 years
9. > 10 years	10. no in-depth inspection		

(8) What are the details of your inspection ?
Select all of the appropriate items below.

		General inspection	In-depth Inspection
a. Decks	1. crack	1.	1.
	2. water leakage	2.	2.
	3. free lime	3.	3.
	4. corrosion	4.	4.
b. Bearings	1. water traps	1.	1.
	2. effect from water leakage	2.	2.
	3. accumulation of dirt and other debris	3.	3.
	4. paint film deterioration	4.	4.
	5. corrosion	5.	5.
	6. defect in bolts, rivets, etc.	6.	6.
c. Girders	1. effect from water leakage	1.	1.
	2. accumulation of dirt and other debris	2.	2.
	3. paint film deterioration	3.	3.
	4. corrosion	4.	4.

	5. defect in bolts, rivets, etc.	5.	5.
d. Expansion joints	1. effect from water leakage	1.	1.
	2. accumulation of dirt and other debris	2.	2.
	3. paint film deterioration	3.	3.
	4. corrosion	4.	4.
	5. defect in deck expansion joint	5.	5.
e. Drainage pipes	1. defect in drainage pipe	1.	1.
	2. effect of water from pipe on other bridge members due to the defect in drainage pipe	2.	2.
	3. effect of water from pipe on other bridge members due to un-appropriate location of pipe	3.	3.

(9) Are there any other items (besides in (8)) which you include in inspection ?
Give them if any.

(10) Do you have any methods to solve the problem of water leakage ?
Give three examples.

1.
2.
3.

(11) How long is the cycle for cleaning dirt, sand, and other debris out of bridge members ?

1. 15 days
2. 1 month
3. 2-3 months
4. 6 months
5. 1 year
6. 2-3 years
7. 4-5 years
8. 6-10 years
9. > 10 years
10. no cleaning

(12) What kinds of environment surround your bridges ?
Select all of the appropriate items below.

1. High concentration of sea-salt particles
2. Acidic rain or acidic fog area
3. High precipitation area
4. Heavy traffic area

5. Industrial area
6. Strong wind from the sea throughout the year
7. Others (   )

Thank you very much for your cooperation.

This questionnaire was sent to 28 administrations in Japan. Only 26 administrations answered the questions and returned the questionnaire. Table 5.1 summaries the results of questionnaire of those 26 administrations.

From these results, the efficiency of maintenance systems is determined in terms of maintenance index, M, by the following equation:

$$M = (P + I) K \tag{5.1}$$

where M represents maintenance index. P represents paint index. I represents inspecting index. K represents environmental index.

Paint index:

Paint index, P, is determined by the following equation:

$$P = 5(P_1) + P_2 \tag{5.2}$$

where P_1 represents the factor of paint type and paint cycle. P_2 represents factor of surface preparation.

The factor of paint type and paint cycle, P_1, is determined based on the answers of questions No. 3 and 4 of the questionnaire. P_1 for each paint cycle and paint type is defined from zero to 100 based on the service life of paint as shown in Table 5.2. P_1 is 100 for the paint cycle that is shorter than service life of paint determined from the line of $\mu - 3\sigma$ of paint film deterioration. P_1 is zero for the paint cycle that is longer than the service life of paint determined by Eq. 3.1. P_1 for other paint cycles varies proportionally between zero and 100.

If there is only one type of paint that is often used, P_1 is obtained directly from Table 5.2. If there are two types or three types of paint that are often used, P_1 is determined by Eq. 5.3 and Eq. 5.4 respectively.

$$P_1 = 0.7(P_{11}) + 0.3(P_{12}) \tag{5.3}$$

$$P_1 = 0.6(P_{11}) + 0.3(P_{12}) + 0.1(P_{13}) \tag{5.4}$$

where P_{11} represents the factor of paint type and paint cycle for the first most often used paint type. P_{12} represents the factor of paint type and paint cycle for the second most often used paint type. P_{13} represents the factor of

Table 5.1−1 Results of the questionnaire of 26 administrations

Problem No.	Item No.	Administration No.																										Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
(1)	1.							x		x			x				x									x		5
	2.			x			x				x				x	x												5
	3.								x										x									2
	4.																						x		x		x	3
	5.					x						x		x							x			x				5
	6.		x																									1
	7.	x			x															x		x						4
(2)	1.																											0
	2.						x		x		x	x														x		5
	3.					x		x							x	x	x						x	x				7
	4.	x	x	x										x								x			x		x	7
	5.																					x						1
	6.																											0
	7.																											0
	8.																											0
(3)	1.	3	1	1	3	1	3	2	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	2	1	25
	2.	2	3	2	1	2	1	1	2		2	2			2		1	2		2	2		3	2	2		2	19
	3.						2											3				3		3		1	3	6
	4.	1			2																							2
	5.		2	3									2								3	2	2					6
	6.																											0
(4) Alkyd resins	1.																											0
	2.																											0
	3.				x			x								x										x		4
	4.						x							x				x		x	x	x					x	12
	5.			x		x			x	x	x	x	x		x			x	x				x	x	x			8
	6.																											0
	7.	x																										1
	8.		x																									1
(4) Chlorinated rubber	1.																											0
	2.																											0
	3.				x			x	x												x							4
	4.						x				x	x					x	x		x								6
	5.														x			x						x	x		x	5
	6.			x		x																	x					3
	7.	x																										1
	8.																											0
(4) Expoxy resins	1.																											0
	2.																											0
	3.																									x		1
	4.						x											x										2
	5.																	x				x		x			x	4
	6.																											0
	7.																											0
	8.																											0
(4) Polyurethane resins	1.																											0
	2.																											0
	3.				x																							1
	4.																											0
	5.																											0
	6.																											0
	7.																											0
	8.																											0
(4) Tar-expoxy resins	1.																											0
	2.																											0
	3.																											0
	4.																											0
	5.																											0
	6.			x																		x						2
	7.																											0
	8.		x																									1

Table 5. 1−2 Results of the questionnaire of 26 administrations

Problem No.	Item No.	Administration No.																										Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
(5)	1.																											0
	2.								x														x					2
	3.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	25
	4.					x														x	x							3
(6)	1.				x					x									x									3
	2.												x											x				2
	3.																											0
	4.	x				x																	x					3
	5.																										x	1
	6.											x			x							x						3
	7.										x							x		x	x							4
	8.							x																				1
	9.																											0
	10.																											0
	11.		x	x			x		x					x		x	x								x	x		9
(7)	1.																											0
	2.																											0
	3.								x																			1
	4.																											0
	5.						x			x			x	x			x	x	x	x	x							9
	6.			x				x				x				x						x					x	6
	7.				x										x									x				3
	8.	x				x					x																	3
	9.																											0
	10.		x																				x		x	x		4
(8)	a. 1.	xx			x	xx	x	x	x	x	xx	xx	xx	x	xx	x	x	xx	x	x	xx	x	x	xx			xx	16 16
	a. 2.	xx			x	x		x	x	x	x	xx	x	x	xx	x	x	x	x	x	x	xx	x	x			x	5 20
	a. 3.	x			x	x		x	x	x	x	xx	x			x	x	x	x	x	x	xx		x			x	2 18
	a. 4.	x			x	x	x	x	x		x	xx	x		xx	x	x	x	x	x	x	xx	x	x			xx	5 19
Left: General inspection	b. 1.	x			x	x		x	x		x	x	x		xx	x	x	x	x	x	x	xx		x			x	2 18
	b. 2.	x			x	x		x	x		x	x	x			x	x	x	x	x	x	xx		x			x	1 17
	b. 3.	x			x	x		x	x	x	xx	x	x	x	x		x	x	x		x	xx		x			xx	4 17
	b. 4.	x		x	x	x	x	x	x	x	x	x	x	x	xx	x	x	x	x	x	x	xx		x			x	2 22
	b. 5.	xx		x	x	x	x	x	x		x	x	x	x	xx	x	x	x	x	x	x	xx		x			xx	4 21
Right: In-depth inspection	b. 6.	xx		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	xx		x			x	2 22
	c. 1.	x			x	x		x	x		x	x	x			x	x	x	x	x	x	xx		x			x	1 17
	c. 2.	x			x	x		x	x		x	x			x		x	x	x	x	x	xx	x	x			xx	4 15
	c. 3.	x		x	x	x	x	x	x	x	x	xx	x	x	xx	x	x	x	x	x	x	xx	x	x			x	4 22
	c. 4.	xx		x	x	x	x	x	x	x	x	xx	x	x	xx	x	x	x	x	x	x	xx		x			xx	5 22
	c. 5.	xx		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	xx		x			x	2 22
	d. 1.	x			x	x		x	x		x	x	x			x	x	x	x	x	x		x	x			xx	2 16
	d. 2.	x			x	xx		x	x	x	xx	xx			x		x	x	x		x		x	x			xx	8 12
	d. 3.	x			x	x	x	x	x		x	x	x	x	x	x	x	xx		x	x			x			x	2 22
	d. 4.	xx			x	x	x	x	x		x	x	x	x	x	x	x	xx	x	x	x		x	x			xx	6 17
	d. 5.	xx			x	xx	x	x	x		xx	xx	xx	x	xx	x	x	xx	x	x	xx		x	xx			xx	14 16
	e. 1.	xx		x	xx	x	x	x	x	x	xx	xx	xx	x	xx	x	x	xx	x	x	x	xx	x	x			xx	11 21
	e. 2.	xx		x	x	x		x	x		x	x		x	xx		x	xx	x	x	x	x		x			x	3 18
	e. 3.	x		x	x	x		x	x		x	x			x			xx	x	x	x	x		x			x	1 16
(9)		No answer from any administrations																										

Table 5. 1−3 Results of the questionnaire of 26 administrations

Problem No.	Item No.	Administration No.																										Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
(10)	1.	x			x	x		x	x		x	x		x		x		x	x		x			x	x		x	15
	2.	x				x					x			x				x					x		x		x	8
See	3.	x			x								x	x								x	x		x			7
note	4.		x						x												x							3
below	5.		x																									1
	6.				x																							1
	7.										x																	1
	8.																	x		x								2
	9.																			x								1
	10.																			x								1
	11.																							x				1
	12.																							x				1
(11)	1.																											0
	2.																											0
	3.																											0
	4.																											0
	5.						x								x			x	x									4
	6.																					x	x					2
	7.				x																						x	2
	8.									x		x	x							x								4
	9.			x																								1
	10.	x	x			x		x	x		x			x		x	x							x	x	x		12
(12)	1.						x	x	x			x			x			x								x		7
	2.					x																x	x					3
	3.						x	x									x	x								x		5
	4.	x	x	x	x				x			x	x	x	x	x			x	x		x	x	x	x		x	17
	5.	x			x	x						x				x				x		x	x		x		x	10
	6.	x				x	x	x	x		x	x			x		x	x					x				x	12
	7.																											0

Note: Methods for solving the proomblem of water leakage.

1. Use non-permeable deck
2. Use undrained expansion joints
3. Provide drainage equipments
4. Replace leaky deck
5. Fill the gap between deck and girders
6. Use heavy-coating paint systems
7. Improve drainage pipes
8. Protect bearings against corrosion
9. Repalce expansion joints
10. Use concrete coating
11. Fill the crack with resins
12. Clean water-traps

Table 5.2 Factors of paint type and paint cycle, P_1

Paint type	Paint cycle (year)							
	< 3	3-5	6-8	9-11	12-14	15-17	18-20	> 20
Alkyd resins	100	80	60	40	20	0	0	0
Chlorinated rubber	100	100	80	60	40	20	0	0
Expoxy resins	100	100	100	80	60	40	20	0
Polyurethane resins	100	100	100	80	60	40	20	0
Tar-expoxy resins	100	100	100	100	80	60	30	0

Table 5.3 Factors of inspecting cycle of general inspection I_{c1} and in-depth inspection I_{c2}

Inspecting cycle	Every day	7 days	15 days	1 months	2-3 months	6 months	1 year
I_{c1}	100	90	80	70	60	50	40
I_{c2}	-	-	100	90	80	70	60

Inspecting cycle	2-3 years	4-5 years	> 5 years	6-10 years	> 10 years	No inspection
I_{c1}	30	20	10	-	-	0
I_{c2}	50	40	-	30	20	0

paint type and paint cycle for the third most often used paint type.

The factor of surface preparation, P_2, is defined based on the answer of question No. 5 of the questionnaire. The factor of surface preparation for surface preparation of type 1, type 2, type 3, and type 4 are 100, 75, 50, and 25 respectively.

Inspecting index:

Inspecting index, I, is determined based on the answers to questions No. 6, 7, and 8 of the questionnaire by the following equations:

$$I = (I_1 + I_2) / 2 \tag{5.5}$$

$$I_1 = \phi_1 I_{c1} \tag{5.6}$$

$$I_2 = \phi_2 I_{c2} \tag{5.7}$$

where I_1 represents general inspecting index. I_2 represents in-depth inspecting index. I_{c1} represents the factors of the inspecting cycle of general inspection. I_{c2} represents the factors of the inspecting cycle of in-depth inspection. ϕ_1 represents the factor of inspecting proportion of general inspection. ϕ_2 represents the factor of inspecting proportion of in-depth inspection.

I_{c1} and I_{c2} are defined for each inspecting cycle as shown in Table 5.3. The factor of inspecting proportion ϕ_1 and ϕ_2 are determined based on the answer to question No. 8 of the questionnaire.

The factor of inspecting proportion ϕ_1 and ϕ_2 are the summation of proportional factors of each type of bridge member (decks, bearings, girders, expansion joints, and drainage pipes). For general inspection, proportional factors for each type of bridge members is zero if there is no selected item of inspection. The proportional factor equals 0.2 if there is at least one inspecting item selected.

For in-depth inspection, proportional factors for each type of bridge member equals 0.2 if there are at least 70 % of the inspecting items selected. Proportional factor for each type of bridge members equals 0.1 if there are at least 30 % but still less than 70 % of the inspecting items selected. The proportional factor for each type of bridge member equals zero if the selected inspecting items are less than 30 %.

Environmental index:

Environmental index, K, is assigned based on the answer of question No. 12 of the questionnaire.

$$K = k_1 k_2 k_3 \tag{5.8}$$

where k_1 represents factor of sea-salt particles. k_2 represents factor of sulfur-dioxide. k_3 represents factor of precipitation.

The factor of sea-salt particles, k_1, is assigned based on the answers of item 1 and item 6 of question No. 12 of the questionnaire. If only item 1 or both item 1 and item 6 are selected, k_1 is 0.7. If only item 6 is selected, k_1 is 0.85. If both item 1 and item 6 are not selected, k_1 is 1.0.

The factor of sulfur-dioxide, k_2, is assigned based on the answers of item 2, item 4, and item 5 of question No. 12 of the questionnaire. If all of the three items are selected, k_2 is 0.8. If only one or two items are selected, k_2 is 0.9. If all of them are not selected, k_2 if 1.0.

The factor of precipitation, k_3, is assigned based on the answer of item 3 of question No. 12 of the questionnaire. If item 3 of question No. 12 is selected, k_3 is 0.9. If item 3 of problem No. 12 is not selected, k_3 is 1.0.

Example of the calculation in the case of normal level of maintenance:

Paint index; $P = 5(P_1) + P_2$

Paint cycle = expected service life of paint determined by Eq. 3.1; $P_1 = 20$
Surface preparation = type 3; $P_2 = 50$
Therefore paint index $P = 5(20) + 50 = 150$

Inspecting index; $I = (\phi_1 I_{c1} + \phi_2 I_{c2}) / 2$

General inspection; Decks, expansion joints and drainage pipes are inspected. Bearings or girders are inspected. The inspecting cycle is 2-3 months.

$$\phi_1 = 0.8, \qquad I_{c1} = 60$$

In-depth inspection; At least 70 % of the inspecting items of each type of bridge members are inspected. The inspecting cycle is 2-3 years.

$$\phi_2 = 1.0, \qquad I_{c2} = 50$$

Therefore inspecting index $I = (0.8(60) + 1.0(50)) / 2 = 49$

Environmental index; $K = k_1 k_2 k_3$

For a normal environment; The contamination of sea-salt particles and sulfur-dioxide in the atmosphere is not so much. Precipitation is not so high.
For marine environment; $K = (0.85)(0.9)(1.0) = 0.77$
For other environments; $K = (1.0)(0.9)(1.0) = 0.9$

Maintenance index; $M = (P + I) K$

For marine environment; $M = (150 + 49)\ 0.77 = 153$

For other environments; M = (150 + 49) 0.9 = 179

The results of the determined maintenance index, M, for 26 administrations are shown in Table 5.4. From these results and the results of the classification of bridge deterioration in Table 4.32, the level of maintenance is classified into four levels based on the following considerations:

Level 1, very good maintenance system: A very good maintenance system is classified for any maintenance system if no bridge under that maintenance systems falls into class 1, class 2, class 3, and class 4 in the classification of bridge deterioration.

Level 2, good maintenance system: A good maintenance system is classified for any maintenance system if there is no bridge under that maintenance systems which falls into class 1, class 2, and class 3 in the classification of bridge deterioration.

Level 3, normal maintenance system: Normal maintenance system is classified for any maintenance systems if there is no bridge under that maintenance system which falls into class 1 and class 2 in the classification of bridge deterioration.

Level 4, poor maintenance system: Poor maintenance system is classified for any maintenance systems if there are any bridges under that maintenance system which fall into class 1 or class 2 in the classification of bridge deterioration.

From the above considerations, the values of maintenance index that should fall in each level of bridge maintenance are as follows:

1) Very good maintenance system

No case study

2) Good maintenance system

Maintenance system of bridges in city C: No corresponding administration
Maintenance system of bridges in city D: M = 414
Maintenance system of bridges in city E: M = 270
Maintenance system of bridges in city G_1: M = 243
Maintenance system of bridges in city G_2: M = 284

3) Normal maintenance system

Normal case in marine environment: M = 153
Normal case in other environments: M = 179

4) Poor maintenance system

Maintenance system of bridges in city A: M = 45
Maintenance system of bridges in city B: M = 77
Maintenance system of bridges in city F: M = 128

Based on the above results, the criteria for judgment of the level of maintenance system are defined as follows:

Level	Criterion	Judgment
1	$M \geq 450$	Very good maintenance system
2	$240 \leq M < 450$	Good maintenance system
3	$150 \leq M < 240$	Normal maintenance system
4	$M < 150$	Poor maintenance system

From this classification, 26 administrations are divided into three groups based on the level of bridge maintenance. The maintenance systems of 14 administrations are classified as good maintenance system. Normal maintenance system is classified for seven administrations. The remaining five administrations perform poor maintenance system.

Table 5.4 Maintenance index, M, for 26 administrations

Order of M	Admin-istra. No.	Corres-ponding city	Paint index P	Inspec index I	Environ. index K			Mainten. index M	M'=P+I	Order of M'
					k1	k2	k3			
1	4	City D	430	20	1.0	0.9	1.0	414	460	2
2	20	-	298	16	1.0	1.0	1.0	336	336	9
2	15	-	350	0	1.0	0.9	1.0	336	373	6
4	25	-	490	0	0.7	1.0	0.9	309	490	1
5	16	-	350	0	0.85	1.0	0.9	288	377	5
6	7	City G_2	420	12	0.7	1.0	0.9	284	451	3
7	9	-	250	40	1.0	1.0	1.0	282	282	17
8	12	-	250	54	1.0	0.9	1.0	274	304	13
9	19	-	268	16	1.0	0.9	1.0	273	303	14
10	21	-	290	50	1.0	0.8	1.0	272	340	8
11	3	City E	290	0	1.0	0.9	1.0	270	300	15
12	10	-	280	32	0.85	1.0	1.0	264	311	12
13	6	City G_1	370	0	0.7	1.0	0.9	243	385	4
14	26	-	260	60	0.85	0.9	1.0	241	315	11
15	13	-	250	0	1.0	0.9	1.0	239	265	18
16	8	-	323	0	0.7	0.9	1.0	226	359	7
17	23	-	200	36	1.0	0.9	1.0	214	238	19
18	11	-	280	40	0.7	0.9	1.0	205	325	10
19	17	-	250	24	0.7	1.0	0.9	184	292	16
19	18	-	150	60	1.0	0.9	1.0	184	204	21
21	24	-	180	0	1.0	0.9	1.0	162	180	23
22	22	-	175	56	0.85	0.8	1.0	138	203	22
22	14	-	180	50	0.7	0.9	1.0	138	219	20
24	5	City F	138	28	0.85	0.9	1.0	128	167	24
25	1	City B	50	70	0.85	0.9	1.0	77	100	25
26	2	City A	50	0	1.0	0.9	1.0	45	50	26

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6 CONCLUSIONS

Corrosion deterioration characteristics of structural steel bridges have been clarified in this research study. The first step to understand the corrosion behavior of steel bridges is to understand the corrosion behavior of steel materials. Next is to clarify the deterioration behavior of paint, and to determine the service life of paint. Corrosion of painted steel materials can be determined based on these results. After that, corrosion deterioration behaviors of structural steel bridges are determined based on corrosion behavior of painted steel materials and the results of bridge survey.

The model for determining the effect of corrosion on the strength of bridge members and the model for determining the safety of existing bridges have been developed. Based on the knowledge of corrosion deterioration characteristics of structural steel bridges, the methods for protecting bridges against corrosion were proposed. Finally, the model for determining the efficiency of maintenance systems was proposed. The results of the research can be concluded for each chapter as follows:

Chapter 2:

The corrosion process of bare steel has been clarified in this chapter. Environmental factors that greatly influence the rate of steel corrosion are temperature, humidity, precipitation, sulfur-dioxide, and sea-salt particles. Long-term corrosion of bare steel can be predicted based on the results of steel exposure test. The results showed that exponential equation $Y = k \ t^m$ gives a good representation of the corrosion behavior of bare steel. Where Y represents corrosion depth. t represents exposure time, k and m are constants.

In the case of no result of steel exposure tests instead, corrosion depth at certain exposure times can be determined based on the data of environmental factors. Two groups of regression equations for predicting corrosion at certain exposure times as a function of environmental factors were determined. Group one is for steel materials that are exposed to rain. The other group is for steel materials that are not exposed to rain. After that, the long-term corrosion of bare steel can be predicted based on this determined corrosion depth at some certain exposure times.

The methods for protecting steel materials that are exposed to atmospheres against corrosion can be classified into five groups. They are coatings, metallic coatings, cathodic protection, alloyings, and control of environments.

Chapter 3:

Service life of paint for structural steel bridges was determined in this chapter. Data of paint film deterioration for each bridge member were collected from existing bridges by means of rating number. Regression equations of paint film deterioration and service life of paint were determined based on these data. Main factors that influence the rate of paint film deterioration are atmospheric environments, structural details, types of paint, thickness of paint film, and steel surface preparation.

The results showed that the service life of paint varies depending on factors such as atmospheric environments, paint types, and parts in a bridge. The service life of paint in marine environment is obviously shorter than the service life of paint in other environments. Chlorinated rubber gives a longer service life than alkyd resins. As for structural details of a bridge, service life of paint applying on shoes is extremely shorter than other parts.

The average service life of paint for steel bridges exposed to rural and city environments are 5.3 years for alkyd resins, and 5.6 years for chlorinated rubber. The average service life of paint for steel bridges exposed to mountainous environment is 4.9 years for alkyd resins. The average service life of paint for steel bridges exposed to marine environments are 4.9 years for alkyd resins, and 5.4 years for chlorinated rubber. Note that service life of alkyd resins exposed to mountainous environment is as short as in marine environment. This is because of the effects of acidic rain and acidic fog that occur highly in this mountainous environment.

As for the effect of thickness of paint film and steel surface preparation on service life of paint, unfortunately these data were not available. Therefore, the effect of thickness of paint film and steel surface preparation on service life of paint could not be clarified, and this is left for the future investigations.

Chapter 4:

Corrosion deterioration characteristics of structural steel bridges have been clarified in this chapter. First, data of corrosion deterioration of bridge members were collected from existing bridges by means of rating number of steel corrosion. The relationship between the rating number of steel corrosion and corrosion depth was determined based on the results of plate thickness measurement of corroded bridge members and scrap materials. The results showed that the rating number of steel corrosion has a good relationship with corrosion depth.

Data of corrosion depth in terms of rating number of steel corrosion were converted to corrosion depth. From this result, the relationship between corrosion depth of bridge members and exposure time of the steel surface after the expiration of paint life was determined for each bridge member and environment. The results showed that the rate of corrosion of bridge members significantly varies depending on structural details of bridges and atmospheric environments. The most corrosive bridge members are shoes and expansion joints of both external girders and internal girders. The most corrosive environment for steel bridges is marine environment.

Next, the methods for predicting uniform corrosion and local corrosion of painted steel materials were proposed. Corrosion depth of painted steel materials was determined based on the corrosion behavior of bare steel and the service life of paint. Corrosion depth of painted steel materials was determined for the same atmospheric condition of each bridge member. This results and the results of bridge survey were used for calibration in order to determine corrosion ratio, which represents the difference in the rate of steel corrosion between normal painted steel material and each bridge member. After that, corrosion of bridge members can be predicted based on corrosion behavior of bare steel, service life of paint, and corrosion ratio. The results showed that corrosion depth predicted by this model accords well with corrosion depth of existing bridges from survey.

The effect of corrosion on the strength of bridge members was determined in terms of stress ratio, which is the ratio of stress value of a corroded section of bridge members to stress value of an original uncorroded section. Maximum and/or local corrosion depth that has a more significant effect on the strength of bridge members than uniform corrosion was converted to effective corrosion depth before determining its effect on the strength of bridge members, This stress ratio shows the percent of increase in stress level on bridge members due to corrosion on condition that the bridge has to resist the same amount of load before and after corroding. The invert of stress ratio shows the remaining percent in stress capacity of bridge members due to corrosion if the stress that occurs in bridge members is limited to be the same value before and after corroding.

Simple but effective methods for determining the safety of existing bridges have been developed. The safety of existing bridges due to corrosion deterioration was determined in terms of deteriorating index. Two methods for determining the safety of existing bridges were developed based on the field data of corrosion deterioration of bridge members. Method one was to evaluate the global deterioration of the existing bridges by means of overall deteriorating index. The other was to evaluate the local deterioration of the existing bridges by means of local deteriorating index.

The results showed that deteriorating index has a good relation with the actual condition of bridge deterioration. Deteriorating index is high for a bridge that highly corrodes. Bridges are considered to be possibly unsafe due to corrosion deterioration when overall deteriorating index is greater than or equal to 0.7, or when local deteriorating index is greater than or equal to 25.

Criteria for judgment of bridge safety are as follows:

Overall deterioration

Class	Criterion	Judgment
S1	$Z1 \geq 1.1$	very severe damage, very deficient bridge
S2	$0.7 \leq Z1 < 1.1$	severe damage, deficient bridge
S3	$0.4 \leq Z1 < 0.7$	significant damage, may develop to class S2,
S4	$0.1 \leq Z1 < 0.4$	small damage, no significant effect on bridge safety
S5	$Z1 < 0.1$	safety

Local deterioration

Class	Criterion	Judgment
S1	$Z2 \geq 100$	very severe damage, very deficient bridge
S2	$25 \leq Z2 < 100$	severe damage, deficient bridge
S3	$10 \leq Z2 < 25$	significant damage, may develop to class S2,
S4	$3 \leq Z2 < 10$	small damage, no significant effect on bridge safety
S5	$Z2 < 3$	safety

Note: A deficient bridge is not necessary an unsafe bridge. But it has the possibility to be unsafe.

Performance activity for each class of bridge deterioration was not proposed in this research study since there was no case study, and this is left for the future investigations.

Chapter 5:

Protection of steel bridges against corrosion has been studied in this chapter. Protection of bridges against corrosion can be performed at the beginning stage of structural design. The possibility of bridge maintenance and inspection against corrosion after construction should be taken into consideration. After completion of the bridges, protection of steel bridges against corrosion involves mainly bridge maintenance and inspection. With the good design of bridges and the adequate maintenance and inspection, a long service life of bridges can be expected.

Corrosion protection of structures begins at the design desk. Good design should performed in order that all of the bridge members can be reached and inspected. The other point of good design is to design the bridge members so they are not prone to corrosion. Certain problems that will be the cause of corrosion should be avoided. Total exposed surfaces of steel should be easily accessible for painting and maintenance. Extra protection should be provided to parts or areas which are inaccessible. For example, metallic coatings, additional painting or both should be provided. The other general considerations are to design the structures so as not allow water-traps and to design in order that wind can circulate throughout the structures.

The essential reason for performing proper bridge maintenance is to insure safety for public use of bridges. Several levels of bridge maintenance can be performed. In general, bridge maintenance involves cleaning, protecting and performing relatively minor repairs to a bridge before deterioration becomes so extensive that rehabilitation or replacement is required. Inspections should not only be confined to searching for defects that may already exist, but also should seek potential problems that require preventive action. Inspections are valuable not only for evaluating maintenance activities, but also for providing resource data for planning, and design. These data are necessary for improving the future overall condition of bridges.

The simple model for determining the efficiency of a maintenance system has been developed. A questionnaire of bridge maintenance and inspection was sent to 28 administrations that have steel bridges in supervision. The results of the questionnaire were used for determining the efficiency of the maintenance system. The efficiency of maintenance system was determined in terms of maintenance index. Maintenance index of a good maintenance system is higher than maintenance index of a poor maintenance system. The criteria for judgment of the level of maintenance system are defined as follows:

Level	Criterion	Judgment	Corresponding classes of bridge deterioration
1	$M \geq 450$	Very good maintenance system	S5
2	$240 \leq M < 450$	Good maintenance system	S4
3	$150 \leq M < 240$	Normal maintenance system	S3
4	$M < 150$	Poor maintenance system	S2, S1

APPENDIX

APPENDIX

Table A1-1 Data of paint film deterioration and steel corrosion of bridges in City A (No.1)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
1	Alkyd resins	P	1(1)	1	1(1)	1	1(1)	1	1(1)	1(G)	1(1)	1(1)	1(1)	1(1)	1(1)
		S	G(G̈)	E	E(G)	E	E(G)	E	E(G)	F(G)	G(G̈)	E(G)	E(G)	E(G)	F(G)
2	Alkyd resins	P	1	4	4	4	4	4	4	4	-	-	4	-	-
		S	E	A	A	A	A	A	A	A	-	-	A	-	-
3	Alkyd resins	P	1	1	(1)	2	4	-	-	2	1	2	-	-	2
		S	G	F	(G)	B	A	-	-	B	G	B	-	-	A
4	Alkyd resins	P	1	3	4	2	4	2	3	3	(1)	1	2	1	1
		S	E	A	A	B	A	B	A	A	(F)	E	B	E	E
5	Alkyd resins	P	1	4	3	4	4	4(1)	3	4	(1)	4(1)	4(1)	3	3
		S	F	A	A	A	A	A(F)	A	A	(G)	A(F)	A(F)	A	A
6	Alkyd resins	P	1	3	2(1)	2	3	3(1)	3(1)	1(1)	1	3	3	2(1)	2(1)
		S	G̈	E	E(G̈)	E	C	B(G̈)	C(G̈)	E(G)	G̈	A	C	C(G̈)	B(G)
7	Alkyd resins	P	(1)	1	(1)	1	-	1	-	1	1	1	1	1	1
		S	(G̈)	F	(G)	E	-	E	-	E	F	E	E	E	E
8	Alkyd resins	P	1(1)	2(1)	2(1)	3(1)	3(1)	3(1)	1(1)	3(1)	2(1)	3(1)	3(1)	3	3
		S	E(G̈)	B(G̈)	C(G̈)	B(G)	B(G)	B(G̈)	D(G̈)	B(G)	C(G̈)	A(C)	B(G̈)	B	B
9	Alkyd resins	P	1	2	4	2	3	2	2	2	1	4	2	3	3
		S	D	B	A	B	B	B	C	D	E	A	B	B	B
10	Alkyd resins	P	1(1)	3(1)	2(1)	2	2(1)	2	1(1)	2	1	1	2	1(1)	1
		S	1(G̈)	B(F)	B(F)	B	C(E)	C	E(G)	D	G̈	E	C	E(G)	F
11	Alkyd resins	P	3	4	4	4	4	4	4	4	-	-	-	-	-
		S	B	A	A	A	A	A	A	A	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G̈ = G'

Table A1-2 Data of paint film deterioration and steel corrosion of bridges in City A (No.1)
For middle part of the span, Rural environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
1	15,02	P	-	1	1(1)	1	1(1)	1(1)	1(1)	1(1)	-	1(1)	1(1)	1(1)	1(G)
		S	-	E	E(G)	E	E(G)	E	E(G)	E(G)	-	E(G)	E(G)	E(G)	E(G)
2	5,08	P	-	4	4	4	4	4	4	4	-	-	-	-	-
		S	-	A	A	A	A	A	A	A	-	-	-	-	-
3	12,05	P	-	1	2	3	4	-	-	2	-	3	4	-	2
		S	-	B	B	A	A	-	-	B	-	A	A	-	B
4	10,02	P	-	3	4	-	4	2	3	3	-	1	2	1	1
		S	-	A	A	-	A	B	A	A	-	E	C	E	E
5	2,04	P	-	4	4	4	4	4	4	3	-	4	4	4	3
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
6	8,02	P	-	3	3(1)	3	4	3	3(1)	2(1)	-	3(1)	3	2(1)	2(1)
		S	-	E	E(G̈)	E	C	E	C(G̈)	E(G)	-	B(G̈)	B	C(G̈)	B(G)
7	28,00	P	-	-	-	-	-	-	-	-	-	-	1	-	-
		S	-	-	-	-	-	-	-	-	-	-	E	-	-
8	9,02	P	-	2	2(1)	3	3	(1)	(1)	2	-	3	2	-	2
		S	-	C	B(F)	B	B	(E)	(E)	C	-	B	B	-	C
9	12,05	P	-	3	3	3	3	-	1	3	-	3	3	-	3
		S	-	B	B	B	B	-	D	B	-	B	B	-	B
10	14,08	P	-	2	2	2	1	2	1	1	-	1(1)	1(1)	(1)	1(1)
		S	-	C	D	B	C	A	A	E	-	E(F)	D(G)	(G)	E(G)
11	3,02	P	-	4	4	4	4	4	4	4	-	-	-	-	-
		S	-	A	A	A	A	A	A	A	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G̈ = G'

Table A1-3 Data of paint film deterioration and steel corrosion of bridges in City A (No.2)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
12	Alkyd resins	P	3	3	3	3	3	3	3	3	3(1)	3	3	4	2
		S	D	B	B	A	A	A	B	B	B(F)	A	A	A	B
13	Alkyd resins	P	1	2	2	2	3	3	3	2	1	2	3	3	1
		S	B	B	B	B	B	B	B	C	C	B	B	B	C
14	Alkyd resins	P	1	3	3	4	2	3	2(1)	3	(1)	4(2)	4	4	3
		S	F	C	B	A	B	B	C(Ĝ)	B	(Ĝ)	A(C)	A	A	A
15	Alkyd resins	P	3	4	4	4	4	4	4	4	4	4(1)	4(1)	4	4
		S	B	A	A	A	A	A	A	A	A	A(D)	A(D)	A	A
16	Alkyd resins	P	(1)	1	2	2	2	-	-	1	(1)	2	2	-	1
		S	(G)	E	B	C	C	-	-	E	(G)	B	B	-	D
17	Alkyd resins	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
18	Alkyd resins	P	-	4(1)	3(1)	4	4	-	-	3	-	3(1)	3	-	3(1)
		S	-	A(F)	A(F)	A	A	-	-	A	-	A(G)	A	-	A(G)
19	Alkyd resins	P	1	3(1)	3	3(1)	2(1)	4	-	1	1	3(1)	3(2)	-	2
		S	G	B(F)	B	B(F)	C(G)	A	-	D	G	B(E)	B(C)	-	C
20	Alkyd resins	P	1	3	3	3	3	3	2	2	-	2	3	2	1
		S	D	A	A	A	A	A	B	B	-	B	A	C	E
21	Alkyd resins	P	4(1)	2(1)	4(1)	4	4	3	3	3	4(1)	4	3	-	4
		S	A(G)	B(G)	A(F)	A	A	A	A	A	A(G)	A	A	-	A
22	Alkyd resins	P	1	1	1	2	2	-	1	1(1)	-	-	-	-	-
		S	E	F	F	B	B	-	E	C(E)	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ĝ = G'

Table A1-4 Data of paint film deterioration and steel corrosion of bridges in City A (No.2)
For middle part of the span, Rural environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
12	6,02	P	-	3	3	3	3	4	3	4	-	4	4	4	2
		S	-	A	A	A	A	A	A	A	-	A	A	A	B
13	18,08	P	-	2	3	2	4	1	2	1	-	2	3	3	1
		S	-	B	B	C	A	D	D	C	-	B	B	B	C
14	7,02	P	-	3	2	3	2	-	-	1	-	4	4	-	3
		S	-	B	C	B	C	-	-	D	-	A	A	-	B
15	0,04	P	-	4	4	4	4	4	4	4	-	4(3)	4	4	4
		S	-	A	A	A	A	A	A	A	-	A(B)	A	A	A
16	23,05	P	-	1	1(1)	1	1	-	-	1	-	2	2	2	1
		S	-	D	C(E)	C	C	-	-	D	-	B	B	C	B
17	1,03	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
18	9,03	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
19	17,03	P	-	3	2(1)	3	4(1)	-	-	1	-	2	3	-	3(1)
		S	-	B	C(D)	B	A(D)	-	-	C	-	C	B	-	B(D)
20	7,05	P	-	3	2	3	2	-	-	1	-	2	3	-	1
		S	-	A	B	A	B	-	-	C	-	B	A	-	C
21	7,05	P	-	4(1)	4(1)	4	4	-	-	3	-	3	4	-	3
		S	-	A(F)	A(G)	A	A	-	-	B	-	A	A	-	A
22	9,00	P	-	1	1	2(1)	2	-	-	1	-	-	-	-	-
		S	-	F	F	B(F)	B	-	-	F	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A1-5 Data of paint film deterioration and steel corrosion of bridges in City A (No.3)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
23	Alkyd resins	P	1(1)	-	-	-	-	-	-	1(1)	1(1)	-	-	-	1(1)
		S	E(G)	-	-	-	-	-	-	E(G)	E(G)	-	-	-	F(G)
24	Alkyd resins	P	1	1	4	3	3	-	-	1	1	2	3	-	1
		S	E	B	A	B	B	-	-	C	E	B	B	-	D
25	Alkyd resins	P	4	4	4	4	4	4	4(1)	4	4	4	4	4	4
		S	A	A	A	A	A	A	A(F)	A	A	A	A	A	A
26	Alkyd resins	P	(1)	4	4	4	4	4	4	4	(1)	4	4	4	4
		S	(F)	A	A	A	A	A	A	A	(F)	A	A	A	A
27	Alkyd resins	P	(1)	4	4	4	4	4	4	4	(1)	4	4	4	4
		S	(G)	A	A	A	A	A	A	A	(G)	A	A	A	A
28	Alkyd resins	P	2	4	4	3	4	3	(1)	2	2	4	4	1	2
		S	C	A	A	A	A	A	(G)	D	C	A	A	E	B
29	Alkyd resins	P	1	3	4	4	4	3	-	2	-	3	4	-	4
		S	E	A	A	A	A	A	-	A	-	A	A	-	A
30	Alkyd resins	P	(1)	1	1	1	1	1	1	1	(1)	1	1	1	1
		S	(G)	F	F	F	F	F	F	F	(G)	F	F	E	E
31	Alkyd resins	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
32	Alkyd resins	P	(1)	1(1)	2(1)	1(1)	1	(1)	1	1	1(1)	1(1)	1	1	1
		S	(F)	C(F)	B(G)	C(E)	D	(F)	F	F	E(G)	C(Ğ)	D	F	D
33	Alkyd resins	P	-	1(1)	(1)	2	(1)	1(1)	(1)	(1)	-	1	(1)	(1)	(1)
		S	-	D(F)	(E)	C	(F)	E(F)	(F)	(F)	-	D	(F)	(F)	(F)

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ğ = G'

Table A1-6 Data of paint film deterioration and steel corrosion of bridges in City A (No.3)
For middle part of the span, Rural environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface O.S.	U. Flange L. Surface I.S.	Web O.S.	Web I.S.	L. Flange U. Surface O.S.	L. Flange U. Surface I.S.	L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
23	(55,02)	P	-	-	-	-	-	-	-	1(1)	-	-	-	-	1(1)
		S	-	-	-	-	-	-	-	E(G)	-	-	-	-	F(G)
24	15,07	P	-	1	3	3	2	-	-	1	-	3	3	-	2
		S	-	B	B	B	B	-	-	C	-	A	A	-	B
25	2,06	P	-	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	-	3(1)	4(1)	4(1)	4(1)
		S	-	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	-	A(F)	A(F)	A(F)	A(F)
26	6,04	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
27	7,07	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
28	7,04	P	-	4	4	4	4	4	4	3	-	4	4	4	3
		S	-	A	A	A	A	A	A	A	-	A	A	A	B
29	8,00	P	-	3	4	4	4	4	-	2	-	3	4	-	3
		S	-	A	A	A	A	A	-	B	-	A	A	-	A
30	27,04	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	F	F	F	F	F	F	F	-	F	F	F	F
31	2,04	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
32	23,03	P	-	2	1	1	1	1	1	1	-	3(1)	2	1	1
		S	-	B	D	C	C	D	E	D	-	B(G)	D	E	D
33	24,09	P	-	1	1	1	1	1	1	1	-	1	1	-	1
		S	-	D	D	C	D	E	D	E	-	D	D	-	E

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　G = G'

Table A1-7 Data of paint film deterioration and steel corrosion of bridges in City A (No.4)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
34	Alkyd resins	P	2	3	3	4	4	3	3	3	(1)	3	2	1	2
		S	C	B	A	A	A	B	B	B	(F)	B	B	D	C
35	Alkyd resins	P	1	1	1	3	1	3	1	1	-	-	-	-	-
		S	F	D	E	A	C	A	E	B	-	-	-	-	-
36	Alkyd resins	P	3	3	3	4	4	3	3	3	-	-	-	-	-
		S	A	A	A	A	A	A	A	A	-	-	-	-	-
37	Alkyd resins	P	-	-	-	-	-	-	-	-	1	4	4	4	4
		S	-	-	-	-	-	-	-	-	E	A	A	A	A
38	Alkyd resins	P	2	3	3	3	3	-	-	2	-	-	-	-	-
		S	C	A	A	A	A	-	-	B	-	-	-	-	-
39	Alkyd resins	P	(1)	2	2	2	2	-	-	2	(1)	2	3	-	3
		S	(F)	B	B	C	B	-	-	B	(F)	B	B	-	B
40	Alkyd resins	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
41	Alkyd resins	P	(1)	2	3	3(1)	3(1)	3(1)	3(1)	3(1)	-	-	-	-	-
		S	(Ĝ)	B	B	B(Ĝ)	B(Ĝ)	B(Ĝ)	B(Ĝ)	B(Ĝ)	-	-	-	-	-
42	Alkyd resins	P	1(1)	4	4	4	4	4	4	4	-	4	4	4	4
		S	D(F)	A	A	A	A	A	A	A	-	A	A	A	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ĝ = G'

Table A1-8 Data of paint film deterioration and steel corrosion of bridges in City A (No.4)
For middle part of the span, Rural environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
34	12,05	P	-	2	3	4	4	3	-	3	-	1	2	-	1
		S	-	B	A	A	A	A	-	B	-	C	C	-	D
35	15,06	P	-	1	3	3	4	3	-	1	-	-	-	-	-
		S	-	B	B	A	A	A	-	B	-	-	-	-	-
36	7,08	P	-	3	4	4	3	-	3	3	-	-	-	-	-
		S	-	A	A	A	A	-	A	A	-	-	-	-	-
37	5,08	P	-	-	-	-	-	-	-	-	-	4	4	4	4
		S	-	-	-	-	-	-	-	-	-	A	A	A	A
38	7,04	P	-	3	3	-	4	-	-	2	-	-	-	-	-
		S	-	A	A	-	A	-	-	B	-	-	-	-	-
39	20,07	P	1	2	2	3	3	-	-	3	1	2	3	-	2
		S	D	B	B	B	B	-	-	B	D	B	B	-	B
40	6,09	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
41	8,04	P	-	3	3	3	3	3	3	2	-	-	-	-	-
		S	-	B	B	B	B	B	B	B	-	-	-	-	-
42	4,09	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　G = G'

Table A2-1 Data of paint film deterioration and steel corrosion of bridges in City B (No.1)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
1	Chlorinated rubber	P	1	1	3	1	2	-	-	1	2	3	2	-	1
		S	E	C	B	C	B	-	-	D	C	A	B	-	D
2	Alkyd resins	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	E(G)	C	D	C	D	-	-	F	F	D	D	-	F
3	-	P	-	1	1	1	1	-	-	1	-	-	-	-	-
		S	-	D	D	C	E	-	-	E	-	-	-	-	-
4	Alkyd resins	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	C	D	C	D	D	-	-	D	C	C	D	-	C
5	Chlorinated rubber	P	3	4	4	4	4	4	4	4	3	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
11	-	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	G	F(G)	F	F(G)	F	F	F	F	G	F	F	F	F
12	Alkyd resins	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	G	D	C	D	C	C	C	E	F	C	C	E	E
13	Alkyd resins	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	D	D	C	D	-	-	D	-	C(F)	D	-	E(G)
15	-	P	1	1	1	1	1	1	1	1	2	1	1	1	1
		S	C	E	C	E	D	F	E	F	B	D	E	E	E
16	Chlorinated rubber	P	3	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
18	Chlorinated rubber	P	4	4	4	3	4	-	-	3	-	-	-	-	-
		S	A	A	A	A	A	-	-	A	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ǥ = G'

Table A2-2 Data of paint film deterioration and steel corrosion of bridges in City B (No.1)
For middle part of the span, Marine environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
1	10,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	C	C	C	-	-	E	-	C	C	-	E
2	10,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	D	D	C	D	-	-	E	-	D	D	-	F
3	23,09	P	-	1	1	1	1	-	-	1	-	-	-	-	-
		S	-	D(G)	D	D(G)	E	-	-	E	-	-	-	-	-
4	10,05	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	C	C	D	C	D	-	-	D	C	D	D	-	E
5	6,08	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
11	18,06	P	-	1	1	1	1	-	1	1	-	1	1	1	1
		S	-	E	F	D	E	-	E	F	-	F	E	E	G
12	10,06	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	C	D	D	C	D	-	-	D	C	D	E	-	E(G)
13	23,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	C	C	C	-	-	D	-	C	C	-	D
15	20,10	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	D	C	E	D	F	D	G	-	C	E	E	E
16	1,07	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
18	4,00	P	-	4	4	4	4	-	-	3	-	-	-	-	-
		S	-	A	A	A	A	-	-	A	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A2-3 Data of paint film deterioration and steel corrosion of bridges in City B (No.2)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
19	Alkyd resins	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	F	E	E	E	E	E	E	F	F	E	E	E	F
20	-	P	1	1	-	1	-	1	-	1	-	-	-	-	-
		S	C	C	-	C	-	C	-	F	-	-	-	-	-
21	Chlorinated rubber	P	1	4	4	4	4	4	4	4	1	4	4	4	4
		S	F	A	A	A	A	A	A	A	F	A	A	A	A
22	-	P	3	3	-	1	-	-	-	1	-	-	1	-	1
		S	B	A	-	C	-	-	-	C	-	-	C	-	C
23	Alkyd resins	P	1	2	1	1	1	-	-	1	1	1	1	-	1
		S	D	B	D	C	D	-	-	D	D	D	D	-	D
24	-	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	G	F(Ğ)	F	D	F	F(Ğ)	F	F	G	F	F	F	F
25	-	P	4	4	4	4	4	-	-	4	4	4	4	-	4
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
26	-	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	G	F	E	F	D	-	-	E	G	C	C	-	C
27	Alkyd resins	P	-	2	2	2	2	-	-	1	-	1	2	-	1
		S	-	B	B	B	B	-	-	C	-	C	B	-	C
34	Chlorinated rubber	P	-	-	-	3	3	-	-	3	-	-	-	-	-
		S	-	-	-	A	A	-	-	A	-	-	-	-	-
35	Chlorinated rubber	P	1	-	-	2	1	-	-	1	-	-	-	-	-
		S	E	-	-	B	C	-	-	E	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ğ = G'

Table A2-4 Data of paint film deterioration and steel corrosion of bridges in City B (No.2)
For middle part of the span, Marine environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
19	25,09	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	E	E	E	E	E	E	F	-	E	E	E	F
20	15,11	P	-	1	-	1	-	1	-	1	-	-	-	-	-
		S	-	C	-	C	-	C	-	F	-	-	-	-	-
21	12,02	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
22	11,06	P	-	3	-	1	-	-	-	1	-	-	1	-	1
		S	-	A	-	C	-	-	-	C	-	-	C	-	C
23	10,04	P	-	2	1	2	1	-	-	1	-	1	1	-	1
		S	-	C	D	C	D	-	-	D	-	C	C	-	C
24	26,06	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	F(G)	F	F	F	F	F	F	F	F	F	F	F	F
25	0,05	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
26	30,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	D	D	D	C	-	-	D	-	C	C	-	D
27	8,05	P	-	2	2	2	2	-	-	1	-	1	2	-	1
		S	-	B	B	B	B	-	-	C	-	C	B	-	C
34	6,06	P	-	-	-	3	3	-	-	3	-	-	-	-	-
		S	-	-	-	A	A	-	-	A	-	-	-	-	-
35	25,05	P	-	-	-	2	1	-	-	1	-	-	-	-	-
		S	-	-	-	B	C	-	-	E	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ğ = G'

Table A3-1 Data of paint film deterioration and steel corrosion of bridges in City B (No.3)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
36	Alkyd resins	P	1	1	1	1	1	1	-	1	1	1	1	-	1
		S	D	C	C	C	D	C	-	D	C	D	D	-	E
37	-	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	C(Ĝ)	C	D	-	-	E	-	C	D	-	E
38	Chlorinated rubber	P	-	3	4	3	3	-	-	3	2	4	3	-	3
		S	-	A	A	A	A	-	-	A	B	A	A	-	A
39	Chlorinated rubber	P	4	4	4	4	4	4	-	4	4	4	4	-	4
		S	A	A	A	A	A	A	-	A	A	A	A	-	A
40	Alkyd resins	P	1	2	2	2	1	2	-	1	-	2	1	-	1
		S	G	B	B	B	C	B	-	D	-	B	C	-	C
41	Chlorinated rubber	P	1	-	-	3	-	-	-	1	-	-	-	-	-
		S	C	-	-	A	-	-	-	C	-	-	-	-	-
42	-	P	1	-	-	1	-	-	-	1	-	-	-	-	-
		S	E	-	-	C	-	-	-	D	-	-	-	-	-
43	Chlorinated rubber	P	1	-	-	3	3	-	-	1	-	-	-	-	-
		S	D	-	-	A	A	-	-	D	-	-	-	-	-
44	Chlorinated rubber	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	C	C	C	C	C	-	-	C	C	C	C	-	C
45	Alkyd resins	P	1	1	1	1	1	1	-	1	1	1	1	-	1
		S	D	D	D	D	C	D	-	C	D	C	C	-	D
46	Alkyd resins	P	-	1	1	2	1	-	-	1	-	1	1	-	1
		S	-	C	C	B	C	-	-	C	-	C	C	-	C

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ĝ = G'

Table A3-2 Data of paint film deterioration and steel corrosion of bridges in City B (No.3)
For middle part of the span, Rural environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
36	15,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	C	C	D	-	-	D	-	D	E	-	E
37	18,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	E(G)	C	D	-	-	D(Ĝ)	-	C	D	-	E
38	5,04	P	-	3	4	3	3	-	-	3	-	4	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
39	0,05	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
40	15,00	P	-	2	2	2	1	-	-	1	-	2	1	-	1
		S	-	B	B	B	C	-	-	D	-	B	C	-	C
41	16,07	P	-	-	-	3	-	-	-	1	-	-	-	-	-
		S	-	-	-	A	-	-	-	C	-	-	-	-	-
42	19,05	P	-	-	-	2	-	-	-	1	-	-	-	-	-
		S	-	-	-	B	-	-	-	D	-	-	-	-	-
43	12,05	P	-	-	-	3	3	-	-	1	-	-	-	-	-
		S	-	-	-	A	A	-	-	D	-	-	-	-	-
44	20,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	C	C	C	-	-	C	-	C	C	-	C
45	10,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	D	C	C	-	-	C	-	C	C	-	C
46	10,05	P	-	1	1	2	1	-	-	1	-	1	1	-	1
		S	-	C	C	B	C	-	-	C	-	C	C	-	C

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ĝ = G'

Table A3-3 Data of paint film deterioration and steel corrosion of bridges in City B (No.4)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
47	-	P	1	1	1	1	1	1	-	1	1	1	1	-	1
		S	G	C	C	C	C	D	-	E	G	C	C	-	E
48	Alkyd resins	P	1	1	1	1	2	-	-	1	1	1	1	-	1
		S	C	C	C	C	B	-	-	C	C	C	C	-	C
49	Alkyd resins	P	1	1	1	2	2	-	-	1	1	1	2	-	1
		S	D	C	C	B	B	-	-	C	D	C	B	-	C
50	Alkyd resins	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	C	D	D	D	C	-	-	D	C	C	C	-	C
51	Alkyd resins	P	1	1	1	1	1	1	-	1	-	-	-	-	-
		S	D	C	C	C	C	C(F)	-	E	-	-	-	-	-
52	Alkyd resins	P	1	1	1	2	2	1	-	1	1	1	2	-	1
		S	G	C	C	B	B	C	-	C	G	C	B	-	C
53	Alkyd resins	P	-	-	-	-	-	-	-	-	1	2	2	-	1
		S	-	-	-	-	-	-	-	-	D	B	B	-	C
56	Chlorinated rubber	P	-	3	-	3	-	-	-	1	-	-	-	-	-
		S	-	A	-	A	-	-	-	E	-	-	-	-	-
57	Chlorinated rubber	P	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)
		S	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)
58	-	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)
59	Alkyd resins	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	C(G)	C	C	C	C	C	C	C	C(G)	C	C	C	C

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A3-4 Data of paint film deterioration and steel corrosion of bridges in City B (No.4)
For middle part of the span, Rural environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
47	22,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	C	C	C	C	-	-	E	-	C	C	-	E
48	10,05	P	-	1	1	1	2	-	-	1	-	1	1	-	1
		S	-	C	C	C	B	-	-	C	-	C	C	-	C
49	10,05	P	-	1	2	2	1	-	-	1	-	1	2	-	1
		S	-	C	B	B	C	-	-	C	-	C(G)	B	-	C(G)
50	10,05	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	D	D	D	C	-	-	D	-	C	C	-	C
51	10,05	P	-	1	1	1	1	-	-	1	-	-	-	-	-
		S	-	C	C	C	C	-	-	D	-	-	-	-	-
52	15,05	P	-	1	1	2	2	-	-	1	-	1	2	-	1
		S	-	C	C	B	B	-	-	C	-	C	B	-	C
53	15,05	P	-	-	-	-	-	-	-	-	-	2	2	-	1
		S	-	-	-	-	-	-	-	-	-	B	B	-	C
56	19,06	P	-	3	-	3	-	-	-	1	-	-	-	-	-
		S	-	A	-	A	-	-	-	E	-	-	-	-	-
57	1,06	P	-	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)	-	4(1)	4(1)	4(1)	4(1)
		S	-	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	A(F)	-	A(F)	A(F)	A(F)	A(F)
58	17,10	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	F(G)	-	F(G)	F(G)	F(G)	F(G)
59	17,10	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	C	C	C	C	C	C	C	-	C	C	C	C

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ĝ = G'

Table A3-5 Data of paint film deterioration and steel corrosion of bridges in City B (No.5)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
63	Alkyd resins	P	1	1	1	2	1	2	1	1	1	1	1	1	1
		S	F	C	D	B	E	B	E	E	F	D(Ğ)	E	D	E
64	-	P	-	-	-	-	-	-	-	-	1	-	1	-	2
		S	-	-	-	-	-	-	-	-	E	-	C	-	B
65	-	P	3	3	3	3	3	3	3	3	3	3	3	3	3
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
66	-	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	G	C	D	D	D	-	-	E	G	D	D	-	F
67	-	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	F	D	E	D	E	-	-	E	F	E	E	-	E
68	-	P	1	1	1	3	4	3	4	1	1	4	4	4	3
		S	G	D	C	A	A	A	A	C	G	A	A	A	A
69	-	P	2	1	1	2	2	2	1	1	1	1	1	1	1
		S	C	C	C	B	B	B	C	C	C	C	C	C	C
70	Alkyd resins	P	1	1	1	2	1	1	1	1	1	1	1	1	1
		S	C	C	C	B	C	C	D	C	E	D	C	D	D
71	Alkyd resins	P	1	1	1	1	1	1	1	1	2	1	1	1	1
		S	(G)	C(G)	C	C	C	D(G)	E	D	B	C	C	C	C
72	-	P	(1)	1	1	1	1	-	-	1	(1)	1	1	-	1
		S	(Ğ)	E	C	D	C	-	-	E	(G)	D	C	-	C
73	Alkyd resins	P	-	2	1	1	1	-	-	1	-	1	1	-	1
		S	-	B	C	C	C	-	-	C	-	C(Ğ)	C(Ğ)	-	F(Ğ)

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ğ = G'

Table A3-6 Data of paint film deterioration and steel corrosion of bridges in City B (No.5)
For middle part of the span, Rural environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
63	16,06	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	B	D	E	D	E	-	-	E	C	E	E	-	E
64	10,06	P	-	-	-	-	-	-	-	-	-	-	1	-	1
		S	-	-	-	-	-	-	-	-	-	-	D	-	E
65	3,06	P	4	4	3	3	3	3	3	3	4	3	3	3	3
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
66	18,07	P	-	2	1	1	1	-	-	1	-	1	1	-	1
		S	-	B	C	C	D	-	-	E	-	D	D	-	E
67	10,06	P	-	1	1	1	1	-	-	1	-	1	1	-	1
		S	-	E	E	D	D	-	-	E	-	D	D	-	E
68	10,05	P	-	1	4	3	4	3	-	1	-	4	4	-	1
		S	-	B	A	A	A	A	-	C	-	A	A	-	C
69	10,04	P	-	2	2	3	2	2	2	1	-	1	1	1	2
		S	-	B	B	A	B	B	B	C	-	C	C	C	B
70	10,06	P	-	2	1	3	2	-	-	2	-	1	1	-	1
		S	-	B	C	A	B	-	-	B	-	C	C	-	C
71	10,06	P	-	1	1	2	2	-	-	1	-	1	2	-	1
		S	-	C	C	B	B	-	-	C	-	C	B	-	C
72	10,04	P	-	1	1	2	2	-	-	1	-	1	1	-	1
		S	-	C	C	B	B	-	-	D	-	C	C	-	C
73	17,06	P	-	2	1	1	1	-	-	1	-	1	1	-	1
		S	-	B	C	C	C	-	-	C	-	C(G̈)	C(G̈)	-	C(G̈)

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G̈ = G'

Table A3-7 Data of paint film deterioration and steel corrosion of bridges in City B (No.6)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
74	Alkyd resins	P	(1)	1	-	2	1	2	1	1	-	2	2	1	1
		S	(Ĝ)	B(G)	-	B	F(Ĝ)	B	F(Ĝ)	F(Ĝ)	-	A	B	F	C
75	-	P	(1)	1	1	2	1	1	1	1	(1)	1	1	1	1
		S	(G)	C	C	B	C	C	E	D	(F)	B	B	C	D
76	Alkyd resins	P	(1)	1	2	1	2	1	1	1	2(1)	2	1	1	1
		S	(G)	C	B	C	B	D	D	F	B(G)	B	C	D	F
78	Alkyd resins	P	1	-	(1)	2	1	2	1	1	2	1	3	-	1
		S	D	-	(F)	B	B	B	E	F	B	C	A	-	D
79	Chlorinated rubber	P	4(1)	-	-	4	4	-	-	4	-	-	-	-	-
		S	A(F)	-	-	A	A	-	-	A	-	-	-	-	-
80	Alkyd resins	P	1	4	1	4	4	4	-	1	-	-	-	-	-
		S	F	A	A	A	A	A	-	B	-	-	-	-	-
81	Alkyd resins	P	1	-	-	3	1	-	-	1	-	-	-	-	-
		S	G(Ĝ)	-	-	A	B	-	-	C(Ĝ)	-	-	-	-	-
82	-	P	1	1	1	1	1	1	1	1	-	1	1	1	1
		S	F	C	C	C	C	C	C	D	-	C	C	C	E
83	-	P	1	3	3	3	4	2	2	2	(1)	3	4	2	2(1)
		S	F	A	A	A	A	B	B	B	(G)	A	A	B	B(F)
84	-	P	1	1	1	1	1	1	-	1	1	1	1	-	1
		S	F	C(E)	C(E)	C(E)	C(E)	C(E)	-	D	F	C	C	-	D
85	Alkyd resins	P	1	(1)	1	1	1	(1)	1	1	1	1	1	1	1
		S	F(G)	(F)	C(F)	C(E)	C	(F)	D	E(F)	F	D	D	D	F

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　Ĝ = G'

Table A3-8 Data of paint film deterioration and steel corrosion of bridges in City B (No.6)
For middle part of the span, Rural environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
74	16,10	P	-	2	-	3	1	1	1	1	-	1	1	-	1
		S	-	B	-	B	D(Ġ)	C	D(F)	F	-	C	B	-	C
75	16,06	P	-	1	1	2	1	2	1	1	-	2	1	1	1
		S	-	C	C	B	C	B	C	D	-	B	C	C	D
76	10,06	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	C(F)	C	C	B	C	D	F	-	C	C	D	F
78	16,01	P	-	-	1	2	1	2	-	1	-	1	1	-	1
		S	-	-	C(F)	B	C	B	-	D	-	C	B	-	E
79	4,07	P	-	-	-	4	4	-	-	4	-	-	-	-	-
		S	-	-	-	A	A	-	-	A	-	-	-	-	-
80	7,06	P	-	4	1	4	4	4	-	1	-	-	-	-	-
		S	-	A	A	A	A	A	-	B	-	-	-	-	-
81	10,02	P	-	-	-	4	2	-	-	1	-	-	-	-	-
		S	-	-	-	A	B	-	-	B	-	-	-	-	-
82	24,06	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	B	C	B	C	B	C	C	-	C	C	C	C
83	17,06	P	-	3	3	2	4	1	2	3	-	3	4	2	3
		S	-	A	A	B	A	C	B	A	-	A	A	B	A
84	21,06	P	-	1	1	3	2	-	-	1	-	2	1	-	1
		S	-	B	B	A	B	-	-	C	-	B	B	-	C
85	20,06	P	1	1	1	1	1	-	-	1	1	1	1	-	1
		S	D(F)	C(F)	C(F)	C(F)	C(F)	-	-	D(F)	D	D	D	-	D

Note: P = RN of paint film deterioration   S = RN of steel corrosion
( ) = data of water leakage area   Ġ = G'

Table A3-9 Data of paint film deterioration and steel corrosion of bridges in City B (No.7)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
86	Chlorinated rubber	P	1	2	1	2	2	-	-	2	1	-	-	-	-
		S	D	B	C	B	B	-	-	B	D	-	-	-	-
87	-	P	-	(1)	1	1	1	1	1	1	-	1	1	1	1
		S	-	(G̈)	F(G)	F(G)	F(G)	F(G̈)	F(G̈)	F(G̈)	-	F(G)	F(G)	F(G)	F(G)
88	-	P	1	1	1	2	1	1	1	1	(1)	1	1	1	1
		S	F	C	C	B	C	C	C	C	(G)	B	B	B	F
89	Alkyd resins	P	1	3	2	2	2	2	2	2	-	3(1)	3(1)	2(1)	2(1)
		S	F(G)	A	B	B	B	B	B	B	-	A(F)	A(F)	B(F)	B(F)

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G̈ = G'

Table A3-10 Data of paint film deterioration and steel corrosion of bridges in City B (No.7)
For middle part of the span, Rural environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
86	9,09	P	-	2	2	3	3	-	-	2	-	-	-	-	-
		S	-	B	B	A	A	-	-	B	-	-	-	-	-
87	19,04	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	F	F	F	F	F	F	F	-	F	F	F	F
88	11,06	P	-	2	1	2	1	-	-	1	-	1	1	-	1
		S	-	B	C	B	B	-	-	C	-	B	B	-	C
89	14,07	P	-	3	2	2	3	-	-	2	-	3(1)	4(1)	-	2(1)
		S	-	A	B	B	A	-	-	B	-	A(F)	A(F)	-	B(F)

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G̈ = G'

Table A4-1 Data of paint film deterioration and steel corrosion of bridges in City C (No.1)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
1	Alkyd resins	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
2	Chlorinated rubber	P	(1)	4(1)	4	4	4	4	4	4	-	4(1)	4	4	4
		S	(F)	A(F)	A	A	A	A	A	A	-	A(G)	A	A	A
3	Chlorinated rubber	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
4	Chlorinated rubber	P	1	2	2	3	2	3	-	1	-	1	3	-	1
		S	G	B	B	A	B	A	-	C	-	C	A	-	F
5	Chlorinated rubber	P	4	4	4	4	4	4	4	3	4	4	4	4	3
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
6	Chlorinated rubber	P	3	4	4	4	4	4	4	4	3	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
7	Chlorinated rubber	P	2	4	4	4	4	4	4	3	3	4	4	4	4
		S	B	A	A	A	A	A	A	A	A	A	A	A	A
8	Chlorinated rubber	P	1	3	3	3	3	3	3	2	2(1)	3(1)	2(1)	2	1
		S	D	A	A	A	A	A	A	A	B(F)	A(G)	B(G)	C	E
9	Chlorinated rubber	P	2	4	4	4	4	4	4	1	2	4	4	4	2
		S	B	A	A	A	A	A	A	C	B	A	A	A	B
10	Alkyd resins	P	1	3	3	3	3	3	3	2	-	3	3	3	2
		S	D	A	A	A	A	A	A	B	-	A	A	A	B
11	Chlorinated rybber	P	3	4	4	4	4	4	4	4	3	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
12	Chlorinated rubber	P	3	3	3	4	3	-	-	2	1	4	2	-	2
		S	A	A	A	A	A	-	-	B	D	A	B	-	B

Table A4-2 Data of paint film deterioration and steel corrosion of bridges in City C (No.1)
For middle part of the span, Rural environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
1	0,07	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
2	4,09	P	4(1)	4	4	4	4	4	4	4	4(1)	4(1)	4	4	4
		S	A(E)	A	A	A	A	A	A	A	A(D)	A(F)	A	A	A
3	0,10	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
4	16,03	P	-	1	2	3	2	-	-	1	-	2	2	-	1
		S	-	C	B	A	B	-	-	C	-	B	B	-	C
5	0,07	P	4	4	4	4	4	4	4	3	4	4	4	4	3
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
6	9,07	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
7	7,01	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
8	10,10	P	-	2	3	3	3	-	-	2	-	3	2	-	2
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
9	5,00	P	-	4	4	4	4	4	4	3	-	4	4	4	3
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
10	13,04	P	-	3	3	3	3	3	3	2	-	3	3	3	2
		S	-	A	A	A	A	A	A	B	-	A	A	A	B
11	3,07	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
12	11,09	P	-	3	3	4	3	-	-	2	-	4	2	-	2
		S	-	A	A	A	A	-	-	B	-	A	B	-	B

Table A4-3 Data of paint film deterioration and steel corrosion of bridges in City C (No.2)
For end part of the span, Rural environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
13	Alkyd resins	P	1	3	4	3	3	-	-	3	1	3	3	-	3
		S	D	A	A	A	A	-	-	A	E	A	A	-	A
14	Chlorinated rubber	P	-	1	2	3	3	-	-	1	-	2	3	-	1
		S	-	C	B	A	A	-	-	C	-	B	A	-	C
15	Alkyd resins	P	3	3	3	3	3	3	3	3	3	3	3	3	3
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
16	Alkyd resins	P	4	4	4	4	4	-	-	4	4	4	4	-	4
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
17	Alkyd resins	P	1	1	1(1)	3	2	2	-	1	1	1	1	-	2
		S	C	C	C(F)	A	B	B	-	C	C	C	C	-	B
18	Alkyd resins	P	-	2	-	3	2	-	-	1	-	-	-	-	-
		S	-	B	-	A	B	-	-	C	-	-	-	-	-
19	Polyurethane resins	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
20	Chlorinated rubber	P	1	1	3	2	3	3	3	2	1	3	3	3	1
		S	D	C	A	B	A	A	A	B	C	A	A	A	B
21	Chlorinated rubber	P	1	3	-	2	2	2	-	2	-	-	-	-	-
		S	C	A	-	B	B	B	-	B	-	-	-	-	-
22	Alkyd resins	P	1	3	-	3	3	3	3	2	-	-	-	-	-
		S	D	A	-	A	A	A	A	B	-	-	-	-	-
23	Alkyd resins	P	1	3	-	3	3	2	-	3	-	-	-	-	-
		S	D	A	-	A	A	B	-	A	-	-	-	-	-
24	Alkyd resins	P	1	3	3	3	3	-	-	3	1	3	3	-	1
		S	C	A	A	A	A	-	-	A	C	A	A	-	A

Table A4-4 Data of paint film deterioration and steel corrosion of bridges in City C (No.2)
For middle part of the span, Rural environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
13	5,10	P	-	3	4	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
14	8,08	P	1	2(1)	3	2	2	-	-	1	1	3	2	-	1
		S	E	B(F)	A	B	B	-	-	D	E	A	B	-	D
15	2,10	P	-	3	3	3	3	3	3	3	-	3	3	3	3
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
16	5,00	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
17	5,08	P	-	1	1(1)	3	2	2	-	1	-	1	1	-	2
		S	-	C	C(F)	A	B	B	-	C	-	C	C	-	B
18	8,01	P	-	2	-	3	2	-	-	1	-	-	-	-	-
		S	-	B	-	A	B	-	-	C	-	-	-	-	-
19	1,09	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
20	10,10	P	-	1	3	2	3	3	3	2	-	3	3	3	1
		S	-	C	A	B	A	A	A	B	-	A	A	A	B
21	12,07	P	-	3	-	2	2	2	-	2	-	-	-	-	-
		S	-	A	-	B	B	B	-	B	-	-	-	-	-
22	11,07	P	-	3	-	3	3	3	3	2	-	-	-	-	-
		S	-	A	-	A	A	A	A	B	-	-	-	-	-
23	10,07	P	-	3	-	3	3	2	-	3	-	-	-	-	-
		S	-	A	-	A	A	B	-	A	-	-	-	-	-
24	8,07	P	-	3	3	3	3	-	-	3	-	3	3	-	1
		S	-	A	A	A	A	-	-	A	-	A	A	-	A

Table A5-1 Data of paint film deterioration and steel corrosion of bridges in City D (No.1)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
1	Chlorinated rubber	P	-	2(1)	3	3	3	-	-	1	-	3	3	-	1
		S	-	B(F)	A	A	A	-	-	C	-	A	A	-	C
2	Chlorinated rubber	P	3	3	-	3	-	-	-	3	-	-	-	-	-
		S	A	A	-	A	-	-	-	A	-	-	-	-	-
3	Chlorinated rubber	P	2	3	3	3	3	-	-	3	2	3	3	-	2
		S	B	A	A	A	A	-	-	A	B	A	A	-	B
4	Chlorinated rubber	P	3	2	3	3	3	-	-	2	3	4	3	-	2
		S	A	B	A	A	A	-	-	B	A	A	A	-	A
5	Chlorinated rubber	P	-	2	3	3	3	-	-	3	-	3	3	-	3
		S	-	B	A	A	A	-	-	A	-	A	A	-	A
6	Chlorinated rubber	P	-	2	4	3	3	-	-	1	-	4	4	-	3
		S	-	B	A	A	A	-	-	C	-	A	A	-	A
7	Chlorinated rubber	P	2	2	4	3	3	-	-	2(1)	2	4	4	-	3(1)
		S	B	B	A	A	A	-	-	B(G)	B	A	A	-	A(D)
8	Chlorinated rubber	P	-	-	-	-	-	-	-	-	2(1)	4	3	-	1
		S	-	-	-	-	-	-	-	-	B(G)	A	A	-	C
9	Chlorinated rubber	P	2	2	3	2	3	-	-	2	2	3	3	-	2
		S	B	B	A	B	A	-	-	B	B	A	A	-	B
10	Chlorinated rubber	P	-	2	4	3	3	-	-	3	-	4	3	-	3
		S	-	B	A	A	A	-	-	A	-	A	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A5-2 Data of paint film deterioration and steel corrosion of bridges in City D (No.1)
For middle part of the span, Marine environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
1	13,09	P	-	3	3	3	3	-	-	2	-	3	3	-	3
		S	-	A	A	A	A	-	-	B	-	A	A	-	A
2	11,10	P	-	3	-	3	-	-	-	3	-	-	-	-	-
		S	-	A	-	A	-	-	-	A	-	-	-	-	-
3	12,10	P	-	3	3	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
4	9,08	P	-	3	3	2	3	-	-	2	-	4	4	-	3
		S	-	A	A	B	A	-	-	B	-	A	A	-	A
5	12,10	P	-	3	3	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
6	11,10	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
7	10,04	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
8	8,10	P	-	-	-	-	-	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	-	-	-	-	-	-
9	12,10	P	-	3	3	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
10	10,10	P	-	3	3	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ø = G'

Table A5-3 Data of paint film deterioration and steel corrosion of bridges in City D (No.2)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
11	Chlorinated rubber	P	-	-	-	3	3	-	-	1	-	-	-	-	-
		S	-	-	-	A	A	-	-	C	-	-	-	-	-
12	Chlorinated rubber	P	1	-	-	4	-	-	-	1	-	-	-	-	-
		S	C	-	-	A	-	-	-	D	-	-	-	-	-
13	Chlorinated rubber	P	-	4	1	3	1	-	-	1	-	1	1	-	1
		S	-	A	B	B	A	-	-	A	-	B	C	-	C
14	Chlorinated rubber	P	2	1	1	3	3	-	-	1	-	-	2	-	1
		S	B	B	A	B	B	-	-	C	-	-	B	-	C
15	Chlorinated rubber	P	1	1	-	2	-	-	-	1	1	1	2	-	1
		S	B	B	-	B	-	-	-	D	B	B	B	-	D
16	Chlorinated rubber	P	1	1	1	3	3	-	-	1	1	-	-	-	-
		S	B	B	B	A	A	-	-	C	B	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ġ = G'

Table A5-4 Data of paint film deterioration and steel corrosion of bridges in City D (No.2)
For middle part of the span, Marine environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
11	9,05	P	-	-	-	3	4	-	-	1	-	-	-	-	-
		S	-	-	-	A	A	-	-	C	-	-	-	-	-
12	9,05	P	-	-	-	4	-	-	-	1	-	-	-	-	-
		S	-	-	-	A	-	-	-	B	-	-	-	-	-
13	11,02	P	1	3	4	3	3	-	-	1	-	2	3(1)	-	1
		S	F	B	A	B	A	-	-	A	-	B	B(C)	-	A
14	11,02	P	-	-	-	-	3	-	-	1	-	-	3	-	1
		S	-	-	-	-	B	-	-	C	-	-	B	-	D
15	13,07	P	-	1	-	2	-	-	-	1	-	1	2	-	1
		S	-	B	-	B	-	-	-	D	-	B	B	-	C
16	13,07	P	-	1	2	1	1	-	-	1	-	-	-	-	-
		S	-	B	B	B	B	-	-	C	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ĝ = G'

Table A6-1 Data of paint film deterioration and steel corrosion of bridges in City E (No.1)
For end part of the span, Rural environment (1)

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface O.S.	U. Flange L. Surface I.S.	Web O.S.	Web I.S	L. Flange U. Surface O.S	L. Flange U. Surface I.S	L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
1	Alkyd resins	P	2	3	2	3	4	-	-	2	2	3	3	-	1
		S	C	A	A	B	A	-	-	C	C	A	A	-	C
2	Alkyd resins	P	2	3	-	3	-	-	-	3	-	-	-	-	-
		S	B	A	-	A	-	-	-	A	-	-	-	-	-
6	Alkyd resins	P	3	2	2	3	3	-	-	1(1)	-	-	-	-	-
		S	A	B	B	A	A	-	-	B(E)	-	-	-	-	-
7	Chlorinated rubber	P	2	3	-	3	4	-	-	1	1	-	3	-	1
		S	B	A	-	A	A	-	-	C	B	-	A	-	C
8	Alkyd resins	P	1	3	-	3	-	-	-	1	-	2	3	-	1
		S	F	A	-	A	-	-	-	C	-	B	A	-	B
9	Alkyd resins	P	4	4	4	4	4	-	-	4	4	4	4	-	4
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
10	Alkyd resins	P	4(1)	4	4	4	4	-	-	4	4(1)	4	4	-	4
		S	A(F)	A	A	A	A	-	-	A	A(F)	A	A	-	A
11	Alkyd resins	P	-	2	2	3	3	-	-	1	1	2	3	-	1
		S	-	B	B	A	A	-	-	C	F	B	A	-	C
14	Alkyd resins	P	-	1	-	1	-	-	-	1	-	-	-	-	1
		S	-	C	-	B	-	-	-	E	-	-	-	-	E
16	Alkyd resins	P	4	4	4	4	4	-	-	4	4	4	4	-	4
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
17	Alkyd resins	P	1	3	3	2	3	-	-	1	1	3	3	-	1
		S	C	A	A	B	A	-	-	C	C	A	A	-	C

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ǥ = G'

Table A6-2 Data of paint film deterioration and steel corrosion of bridges in City E (No.1)
For middle part of the span, Rural environment (1)

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
1	8,04	P	-	3	2	3	4	-	-	1	-	3	3	-	1
		S	-	A	A	B	A	-	-	C	-	A	A	-	C
2	9,09	P	-	3	-	3	-	-	-	3	-	-	-	-	-
		S	-	A	-	A	-	-	-	A	-	-	-	-	-
6	7,09	P	-	3	3	4	3	-	-	3	-	-	-	-	-
		S	-	A	A	A	A	-	-	A	-	-	-	-	-
7	6,06	P	-	3	-	3	4	-	-	1	-	-	3	-	1
		S	-	A	-	A	A	-	-	C	-	-	A	-	C
8	9,09	P	-	3	3	3	4	-	-	1	-	2	3	-	1
		S	-	A	A	A	A	-	-	C	-	B	A	-	C
9	0,03	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
10	0,03	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
11	12,01	P	-	2	2	3	3	-	-	1	-	2	3	-	1
		S	-	B	B	A	A	-	-	C	-	B	A	-	C
14	13,02	P	-	1	-	1	-	-	-	1	-	-	-	-	1
		S	-	C	-	B	-	-	-	E	-	-	-	-	E
16	0,03	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
17	12,09	P	-	3	3	2	3	-	-	1	-	3	3	-	1
		S	-	A	A	B	A	-	-	C	-	A	A	-	C

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ø = G'

Table A6-3 Data of paint film deterioration and steel corrosion of bridges in City E (No.2)
For end part of the span, Rural environment (1)

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
18	Alkyd resins	P	4	4	4	4	4	-	-	4	4	4	4	-	4
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
20	Alkyd resins	P	1	3	3	3	3	-	-	1	2	3	3	-	1
		S	C	A	A	A	A	-	-	B	B	A	A	-	B
23	Alkyd resins	P	-	3	3	3	3	-	-	1	-	3	2	-	2
		S	-	A	A	A	A	-	-	B	-	A	B	-	B
24	Alkyd resins	P	-	3	2	3	3	-	-	2	-	3	3	-	3
		S	-	A	A	A	A	-	-	B	-	A	A	-	A
25	Alkyd resins	P	-	3	3	3	3	-	-	1	-	3	3	-	1
		S	-	A	A	A	A	-	-	B	-	A	A	-	C
26	Alkyd resins	P	1	3	3	3	3	-	-	1	1	2	3	-	1
		S	C	A	A	A	A	-	-	C	C	B	A	-	C
27	Alkyd resins (I girder)	P	-	2	1	2	3	-	-	1	-	2	3	-	1
		S	-	B	B	B	A	-	-	C	-	B	A	-	C
27	Alkyd resins (Box girder)	P	1	3	3	3	3	-	-	1	1	2	3	-	2
		S	C	A	A	A	A	-	-	B	C	B	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A6-4 Data of paint film deterioration and steel corrosion of bridges in City E (No.2)
For middle part of the span, Rural environment (1)

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
18	0,03	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
20	10,10	P	-	3	2	3	3	-	-	1	-	2	3	-	1
		S	-	A	B	A	A	-	-	B	-	A	A	-	B
23	12,01	P	-	1	2	2	2	-	-	1	-	1	3	-	1
		S	-	D	B	B	B	-	-	B	-	D	A	-	B
24	8,09	P	-	3	3	3	3	-	-	1	-	3	3	-	1
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
25	12,01	P	-	3	3	3	3	-	-	1	-	3	3	-	1
		S	-	A	A	A	A	-	-	B	-	A	A	-	C
26	12,09	P	-	3	3	3	3	-	-	1	-	2	3	-	1
		S	-	A	A	A	A	-	-	C	-	B	A	-	C
27	13,00	P	-	1	2	3	3	-	-	1	-	2	3	-	1
		S	-	B	B	A	A	-	-	C	-	B	A	-	C
27	10,03	P	-	1	3	2	3	-	-	2	-	2	3	-	2
		S	-	B	A	B	A	-	-	B	-	B	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area A = G'

Table A7-1 Data of paint film deterioration and steel corrosion of bridges in City E (No.3)
For end part of the span, Rural environment (2)

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
32	Alkyd resins	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
34	Alkyd resins	P	-	1	2	1	1	-	-	1	-	2	1	-	1
		S	-	C	B	C	C	-	-	C	-	B	C	-	C
35	Alkyd resins	P	-	2	3	3	3	-	-	2	-	3	3	-	2
		S	-	B	A	A	A	-	-	B	-	A	A	-	B
40	Alkyd resins	P	3	3	3	3	3	-	-	2	3	3	3	-	2
		S	A	A	A	A	A	-	-	B	A	A	A	-	B
41	Alkyd resins	P	-	-	-	-	-	-	-	2	-	-	-	-	3
		S	-	-	-	-	-	-	-	B	-	-	-	-	A
42	Alkyd resins	P	1	2	1	3	3	-	-	1	-	1	3	-	1
		S	C	B	B	A	A	-	-	B	-	B	A	-	B
43	Alkyd resins	P	-	-	-	2	-	-	-	-	-	-	-	-	-
		S	-	-	-	B	-	-	-	-	-	-	-	-	-
44	Alkyd resins	P	1	2	1	3	3	-	-	1	-	1	3	-	1
		S	C	B	B	A	A	-	-	B	-	B	A	-	B
46	Alkyd resins	P	-	2	3	3	3	2	2	2	-	3	3	1	1
		S	-	A	A	A	A	B	B	B	-	A	A	C	B
47	Alkyd resins	P	-	3	3	2	3	2	2	2	-	3	2	2	2
		S	-	A	A	A	A	B	A	A	-	A	B	A	A
48	Alkyd resins	P	1	2	3	3	3	2	3	1	-	3	3	3	1
		S	F	A	A	A	A	A	A	B	-	A	A	A	B

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　0 = G'

Table A7-2 Data of paint film deterioration and steel corrosion of bridges in City E (No.3)
For middle part of the span, Rural environment (2)

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
32	1,01	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
34	11,08	P	-	2	2	1	1	-	-	1	-	2	1	-	1
		S	-	B	B	C	C	-	-	C	-	B	C	-	C
35	7,10	P	-	2	3	3	3	-	-	2	-	3	3	-	2
		S	-	B	A	A	A	-	-	B	-	A	A	-	B
40	3,08	P	-	3	3	3	3	-	-	2	-	3	3	-	2
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
41	11,00	P	-	-	-	-	-	-	-	2	-	-	-	-	3
		S	-	-	-	-	-	-	-	B	-	-	-	-	A
42	6,06	P	-	1	1	3	3	-	-	2	-	2	2	-	2
		S	-	B	B	A	A	-	-	B	-	B	B	-	B
43	11,08	P	-	-	-	-	-	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	-	-	-	-	-	-
44	8,06	P	-	1	1	3	3	-	-	2	-	2	2	-	2
		S	-	B	B	A	A	-	-	B	-	B	B	-	B
46	3,09	P	-	3	3	4	3	3	3	1	-	3	3	2	1
		S	-	A	A	A	A	A	A	B	-	A	A	B	B
47	5,01	P	-	3	3	3	2	3	3	2	-	3	3	3	2
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
48	9,09	P	-	2	3	3	3	3	3	1	-	3	3	3	1
		S	-	A	A	A	A	A	A	B	-	A	A	A	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A7-3 Data of paint film deterioration and steel corrosion of bridges in City E (No.4)
For end part of the span, Rural environment (2)

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
49	Alkyd resins	P	1	3	3	3	3	2	-	1	-	3	3	-	1
		S	E	A	A	A	A	B	-	B	-	A	A	-	B
51	Alkyd resins	P	1	1	1	2	3	2	1	1	1	1	3	1	1
		S	E	B	B	B	A	B	B	B	E	B	A	E	E
52	Alkyd resins	P	1	1	1	1	2	1	1	1	1	1	3	1	2
		S	E	B	B	B	A	D	D	B	F	B	A	C	B
53	Chlorinated rubber	P	-	4	3	4	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A

Table A7-4 Data of paint film deterioration and steel corrosion of bridges in City E (No.4)
For middle part of the span, Rural environment (2)

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
49	9,09	P	-	3	3	3	3	3	-	1	-	3	3	-	1
		S	-	A	A	A	A	A	-	B	-	A	A	-	A
51	11,04	P	-	1	1	2	3	2	-	1	-	1	2	-	1
		S	-	B	B	B	A	A	-	B	-	B	B	-	B
52	11,05	P	-	1	1	1	3	1	1	1	-	1	3	-	2
		S	-	B	B	B	A	C	B	B	-	B	A	-	B
53	6,03	P	-	4	3	4	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A8-1 Data of paint film deterioration and steel corrosion of bridges in City F (No.1)
For end part of the span, Mountainous environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
1	Chlorinated rubber	P	1	3	3	3	3	3	-	2(1)	1	3	3	-	2
		S	F	A	A	A	A	A	-	B(F)	E	A	A	-	B
2	Alkyd resins	P	1(1)	3(1)	2	3	2	3(1)	1(1)	1	1	2	3	1	2
		S	C(G)	A(F)	A	A	B	A(F)	C(F)	C	G	B	A	C	B
3	Alkyd resins	P	2(1)	3(1)	3(1)	3	3(1)	3	-	3	2(1)	3	3	-	3
		S	B(D)	A(F)	A(F)	A	A(F)	A	-	A	B(F)	A	A	-	A
4	Alkyd resins	P	2(1)	3	4	3	4	3	4(1)	2	-	-	-	-	-
		S	B(G)	A	A	A	A	A	A(G)	B	-	-	-	-	-
5	Alkyd resins	P	1(1)	1	1	1	1	1	1	1	1	1	2	1	1
		S	D(G)	C	C	B	C	C	C	C	C	C	B	C	C
6	Alkyd resins	P	1	2	3(1)	3(1)	3	2	3	1	1	3	3	3	1
		S	E	B	A(F)	A(F)	A	B	A	C	D	A	A	A	C
7	Alkyd resins	P	1(1)	3	3	3	3	3	3	2	(1)	3	3	3	2
		S	C(F)	A	A	A	A	A	A	B	(F)	A	A	A	B
8	Alkyd resins	P	4(1)	4	4	4	4	4	4	4	4(1)	4	4	4	4
		S	A(B)	A	A	A	A	A	A	A	A(F)	A	A	A	A
9	Alkyd resins	P	2(1)	3(1)	2(1)	3(1)	2	(1)	(1)	2(1)	2(1)	2	3	2	2
		S	B(Ġ)	A(G)	B(F)	A(G)	B	(G)	(G)	B(F)	B(Ġ)	B	A	B	B
10	Alkyd resins	P	4	4	4	4	4	4	4	4	-	-	-	-	-
		S	A	A	A	A	A	A	A	A	-	-	-	-	-
11	Alkyd resins	P	4	4	4	4	4	4	4	4	-	-	-	-	-
		S	A	A	A	A	A	A	A	A	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ġ = G'

Table A8-2 Data of paint film deterioration and steel corrosion of bridges in City F (No.1)
For middle part of the span, Mountainous environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface O.S.	U. Flange L. Surface I.S.	Web O.S.	Web I.S.	L. Flange U. Surface O.S.	L. Flange U. Surface I.S.	L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
1	16.11	P	-	3	3	3	3	-	-	2	-	3(1)	3	-	2(1)
		S	-	A	A	A	A	-	-	B	-	A(F)	A	-	B(F)
2	10.6	P	-	3	3	3	2	3	2	3	-	-	-	-	2
		S	-	A	A	A	B	A	A	A	-	-	-	-	B
3	7.6	P	-	3	3	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
4	2.6	P	-	3	4	3	4	-	-	3	-	-	-	-	-
		S	-	A	A	A	A	-	-	A	-	-	-	-	-
5	11.3	P	-	1	1	2	2	2	-	1	-	1	1	-	1
		S	-	C	B	B	B	B	-	B	-	C	C	-	C
6	10.2	P	-	2	3	3	3	2	-	2	-	3	3	-	2
		S	-	B	A	A	A	B	-	B	-	A	A	-	B
7	9.2	P	-	3	3	3	3	-	-	2	-	3	4	-	1
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
8	1.5	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
9	9.8	P	-	2	1(1)	3	3	3	2(1)	2	-	2	3	3	3
		S	-	B	B(G)	A	A	A	B(F)	B	-	B	A	A	A
10	0.3	P	-	4	4	4	4	4	4	4	-	-	-	-	-
		S	-	A	A	A	A	A	A	A	-	-	-	-	-
11	0.5	P	-	4	4	4	4	4	4	4	-	-	-	-	-
		S	-	A	A	A	A	A	A	A	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area () = G'

Table A8-3 Data of paint film deterioration and steel corrosion of bridges in City F (No.2)
For end part of the span, Mountainous environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
12	Alkyd resins	P	1	4	4	4	4	3	4	4	-	4	4	4	4
		S	F	A	A	A	A	A	A	A	-	A	A	A	A
13	Alkyd resins	P	3(1)	4	4	4	4	3	4	4	4(1)	4	4	4	4
		S	A(D)	A	A	A	A	A	A	A	A(F)	A	A	A	A
14	Alkyd resins	P	1	1	1	1	1	1	1	1	1	1	1	1	1
		S	F	C	C	C	C	E	E	D	F	C	C	E	C
15	Alkyd resins	P	4	4	4	4	4	4	4	4	(1)	4	4	4	4
		S	A	A	A	A	A	A	A	A	(F)	A	A	A	A
16	Alkyd resins	P	-	4	4	4	4	-	-	2	-	4(1)	4	-	1
		S	-	A	A	A	A	-	-	B	-	A(F)	A	-	B
17	Alkyd resins	P	1	3	-	2	-	2	-	-	-	-	-	-	-
		S	D	A	-	B	-	B	-	-	-	-	-	-	-
18	Alkyd resins	P	3	4	4	4	4	-	-	3	3	4	4	-	3
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
19	Alkyd resins	P	4	4	4	4	4	4	-	4	4	4	4	-	4
		S	A	A	A	A	A	A	-	A	A	A	A	-	A
20	Alkyd resins	P	1	3	3	3	3	-	-	3	2	3	3	-	3
		S	C	A	A	A	A	-	-	A	B	A	A	-	A
21	Alkyd resins	P	1(1)	2	2	3	3	2	2	2	2	2	3	2	2
		S	C(F)	B	B	A	A	B	B	B	B	B	A	B	B
22	Alkyd resins	P	2	3	4	4	4	4	-	3	2	4	4	-	3
		S	B	A	A	A	A	A	-	A	B	A	A	-	A

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　0 = G'

Table A8-4 Data of paint film deterioration and steel corrosion of bridges in City F (No.2)
For middle part of the span, Mountainous environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
12	4.0	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
13	3.6	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
14	12.2	P	-	1	1	1	1	1	1	1	-	1	1	1	1
		S	-	C	C	C	C	D	D	D	-	C	C	D	C
15	2.7	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
16	3.5	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
17	10.8	P	-	3	-	2	-	2	-	-	-	-	-	-	-
		S	-	A	-	B	-	B	-	-	-	-	-	-	-
18	6.11	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
19	3.2	P	-	4	4	4	4	4	-	4	-	4	4	-	4
		S	-	A	A	A	A	A	-	A	-	A	A	-	A
20	10.6	P	-	3	3	3	3	-	-	3	-	3	3	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
21	10.6	P	-	2	2	3	3	2	2	2	-	2	3	2	2
		S	-	B	B	A	A	B	B	B	-	B	A	B	B
22	2.11	P	-	3	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area 0 = G'

Table A8-5 . Data of paint film deterioration and steel corrosion of bridges in City F (No.3)
For end part of the span, Mountainous environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
23	Alkyd resins	P	1(1)	3	3	3	3	3(1)	-	2	1	3	3	-	2
		S	C(Ğ)	A	A	A	A	A(Ğ)	-	B	C	A	A	-	B
24	Alkyd resins	P	4	4	4(1)	4	4	4	4	4	4	4(1)	4	4	4
		S	A	A	A(F)	A	A	A	A	A	A	A(F)	A	A	A
25	Alkyd resins	P	1	4	4	4	4	3	-	3	-	4	4	-	3
		S	F	A	A	A	A	A	-	A	-	A	A	-	A
26	Alkyd resins	P	1(1)	2	2(1)	1	3	2	2	1	-	-	-	-	-
		S	C(F)	B	A(F)	A	A	A	A	B	-	-	-	-	-
27	Alkyd resins	P	2	4	4	4	4	4	4	4	4	4	4	4	4
		S	B	A	A	A	A	A	A	A	A	A	A	A	A
28	Alkyd resins	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
29	Alkyd resins	P	(1)	3	3	3	4	2	2	1	(1)	2	4	2	2
		S	(G)	A	A	A	A	B	B	B	(F)	B	A	B	B
30	Alkyd resins	P	3(1)	3	-	3	3	-	-	3	(1)	3	3	-	3
		S	A(F)	A	-	A	A	-	-	A	(F)	A	A	-	A
31	Alkyd resins	P	1	-	-	3	-	-	-	2	-	-	-	-	-
		S	C	-	-	A	-	-	-	B	-	-	-	-	-
32	Alkyd resins	P	1	1	1	1	1	1	1	1	-	-	-	-	-
		S	G	D	C	C	C	D	C	D	-	-	-	-	-
33	Alkyd resins	P	-	1(1)	2	3(1)	3	1	-	1	-	-	-	-	-
		S	-	B(F)	B	A(D)	A	C	-	C	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ğ = G'

Table A8-6 Data of paint film deterioration and steel corrosion of bridges in City F (No.3)
For middle part of the span, Mountainous environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
23	13.6	P	-	3	3	3	3	-	-	2	-	3	3	-	2
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
24	2.7	P	-	4	4	4	4	4	-	4	-	4	4	-	4
		S	-	A	A	A	A	A	-	A	-	A	A	-	A
25	11.2	P	-	4	4	4	4	3	-	3	-	4	4	-	3
		S	-	A	A	A	A	A	-	A	-	A	A	-	A
26	17.9	P	-	3	3	1	3	-	-	2	-	-	-	-	-
		S	-	A	A	A	A	-	-	A	-	-	-	-	-
27	1.3	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
28	0.6	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
29	14.10	P	-	3	3	3	3	-	-	2	-	3	3	-	1
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
30	4.7	P	-	3	-	3	3	-	-	3	-	3	3	-	3
		S	-	A	-	A	A	-	-	A	-	A	A	-	A
31	10.6	P	-	-	-	3	-	-	-	2	-	-	-	-	-
		S	-	-	-	A	-	-	-	B	-	-	-	-	-
32	30.	P	-	1	1	1	1	1	-	1	-	-	-	-	-
		S	-	D	C	C	C	D	-	D	-	-	-	-	-
33	16.2	P	-	1	2	3	3	-	-	1	-	-	-	-	-
		S	-	B	B	A	A	-	-	C	-	-	-	-	-

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area Ø = G'

Table A8-7' Data of paint film deterioration and steel corrosion of bridges in City F (No.4)
For end part of the span, Mountainous environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
34	Alkyd resins	P	2(1)	4	4	4	4	4	4	3	-	4	4	4	3
		S	B(F)	A	A	A	A	A	A	A	-	A	A	A	A
35	-	P	1	2	-	2	-	1	-	2	-	-	-	-	-
		S	F	B	-	B	-	D	-	B	-	-	-	-	-
36	-	P	1	2	2	1	2	1	-	1	-	2	2	-	1
		S	D	B	B	C	B	C	-	D	-	B	B	-	C

Note: P = RN of paint film deterioration   S = RN of steel corrosion
( ) = data of water leakage area   Ġ = G'

Table A8-8 Data of paint film deterioration and steel corrosion of bridges in City F (No.4)
For middle part of the span, Mountainous environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
34	9.00	P	-	4	4	4	4	4	4	3	-	4	4	4	3
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
35	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-
		S	-	-	-	-	-	-	-	-	-	-	-	-	-
36	-	P	-	2	2	1(1)	2	1	-	1(1)	-	2	2	-	1
		S	-	B	B	C(F)	B	C	-	D(F)	-	B	B	-	C

Note: P = RN of paint film deterioration   S = RN of steel corrosion
( ) = data of water leakage area   Ġ = G'

Table A9-1 Data of paint film deterioration and steel corrosion of bridges in City G (No.1)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface O.S.	U. Flange L. Surface I.S.	Web O.S.	Web I.S	L. Flange U. Surface O.S	L. Flange U. Surface I.S	L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
1	Chlorinated rubber	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
2	Alkyd resins	P	1	2	2	2	2	2	2	2	(1)	2	2	2	1(1)
		S	F	B	B	B	B	B	B	B	(G)	B	B	B	C(F)
3	Expoxy resins	P	-	3	3	3	3	-	-	2	-	3	3	-	2
		S	-	A	A	A	A	-	-	B	-	A	A	-	B
4	Chlorinated rubber	P	2(1)	2	4	4	4	4	4	2	2	4	4	4	2(1)
		S	B(G)	B	A	A	A	A	A	B	B	A	A	A	B(F)
5	Chlorinated rubber	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
6	Chlorinated rubber	P	4	4	4	3	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
7	Alkyd resins	P	1	1	1	3	1	3	-	1	-	1	1	-	1
		S	B	B	B	A	B	A	-	F	-	B	B	-	F
8	Alkyd resins	P	1(1)	2	3	2	3	-	-	1	1	3	2	-	1
		S	D(F)	B	A	B	A	-	-	C	C	A	B	-	D
9	Chlorinated rubber	P	1(1)	2	2	1	2	-	-	1	1	2	2	-	1
		S	D(F)	B	B	C	B	-	-	C	D	B	B	-	C
10	Chlorinated rubber	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
11	Chlorinated rubber	P	4	4	4	4	4	-	-	2	4	4	4	-	4
		S	A	A	A	A	A	-	-	B	A	A	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A9-2 Data of paint film deterioration and steel corrosion of bridges in City G (No.1)
For middle part of the span, Marine environment

No.	Time after repainted (Year,Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
1	2.9	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
2	10.10	P	-	2	2	2	2	2	2	2	-	2	2	2	1
		S	-	B	B	B	B	B	B	B	-	B	B	B	C
3	8.4	P	3	3	3	3	3	-	-	2	3	3	3	-	2
		S	A	A	A	A	A	-	-	B	A	A	A	-	B
4	7.4	P	-	4	4	4	4	4	4	2	-	4	4	4	1
		S	-	A	A	A	A	A	A	B	-	A	A	A	C
5	3.3	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
6	3.3	P	-	4	4	3	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
7	10.8	P	-	1	1	3	1	3	-	1	-	1	1	-	1
		S	-	B	B	A	B	A	-	F	-	B	B	-	F
8	11.4	P	-	2	3	1	2	-	-	1	-	3	1	-	1
		S	-	B	A	C	B	-	-	C	-	A	C	-	D
9	10.3	P	-	2	3	3	3	-	-	2	-	-	-	-	-
		S	-	B	A	A	A	-	-	B	-	-	-	-	-
10	0.3	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
11	2.11	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G̸ = G'

Table A9-3 Data of paint film deterioration and steel corrosion of bridges in City G (No.2)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
12	Alkyd resins	P	4	4	4(1)	4	4	4	4	3	4	4	4	4	4
		S	A	A	A(F)	A	A	A	A	A	A	A	A	A	A
13	Chlorinated rubber	P	4(1)	4	-	4(1)	4	-	-	4	-	-	4	-	4
		S	A(F)	A	-	A(C)	A	-	-	A	-	-	A	-	A
14	Polyurethane resins	P	4(1)	4	4	4	4	4	4	4	4	4	4	4	4
		S	A(F)	A	A	A	A	A	A	A	A	A	A	A	A
15	Alkyd resins	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
16	Alkyd resins	P	-	3	3	3	3	3	3	1	-	3	3	3	2
		S	-	A	A	A	A	A	A	B	-	A	A	A	B
17	Chlorinated rubber	P	1(1)	1(1)	1	1	1	-	-	1	1	-	-	-	-
		S	D(F)	C(F)	C	C	C	-	-	D	D	-	-	-	-
18	Chlorinated rubber	P	1(1)	2	-	2	2	-	-	2	1	-	1	-	2(1)
		S	D(F)	B	-	B	B	-	-	B	D	-	C	-	B(F)
19	Expoxy resins	P	4	-	-	4	4	-	-	4	-	-	-	-	-
		S	A	-	-	A	A	-	-	A	-	-	-	-	-
20	Chlorinated rubber	P	1(1)	3	-	3	4	3	-	2	3	-	4	-	3
		S	D(F)	A	-	A	A	A	-	B	A	-	A	-	A

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　G = G'

Table A9-4 Data of paint film deterioration and steel corrosion of bridges in City G (No.2)
For middle part of the span, Marine environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
12	1.6	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
13	4.5	P	-	4	-	4	4	-	-	4	-	-	4	-	4
		S	-	A	-	A	A	-	-	A	-	-	A	-	A
14	1.3	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
15	4.3	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
16	6.5	P	-	3	3	3	3	3	3	1	-	3	3	3	2
		S	-	A	A	A	A	A	A	B	-	A	A	A	B
17	8.7	P	-	1(1)	1	1	1	-	-	1(1)	-	-	-	-	-
		S	-	C(F)	C	C	C	-	-	C(F)	-	-	-	-	-
18	8.7	P	-	2	-	2	2	-	-	2	-	-	1	-	2
		S	-	B	-	B	B	-	-	B	-	-	C	-	B
19	5.4	P	-		-	4	4	-	-	4	-	-	-	-	-
		S	-		-	A	A	-	-	A	-	-	-	-	-
20	5.3	P	-	3	-	3	4	3	-	2	-	-	4	-	3
		S	-	A	-	A	A	A	-	B	-	-	A	-	A

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A9-5 Data of paint film deterioration and steel corrosion of bridges in City G (No.3)
For end part of the span, Marine environment

No.	Paint type		External girder								Internal girder				
			Shoe	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Shoe	U.F. L.S.	Web	L.F. U.S.	L.F. L.S.
				O.S.	I.S.	O.S.	I.S	O.S	I.S						
21	Alkyd resins	P	4	4	4	4	4	-	-	3	4	4	4	-	3
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
22	Chlorinated rubber	P	4	4	4	4	4	-	-	4	4	4	4	-	4
		S	A	A	A	A	A	-	-	A	A	A	A	-	A
23	Chlorinated rubber	P	1	3	3	1	3	3	3	3(1)	-	3	3	3	3
		S	F	A	A	B	A	A	A	A(F)	-	A	A	A	A
24	Chlorinated rubber	P	(1)	4	4	4	4	3	4	2	(1)	4	4	4	2
		S	(F)	A	A	A	A	A	A	B	(F)	A	A	A	B
25	Chlorinated rubber	P	1	2	4	4	4	4	4	1	1	4	4	4	1
		S	F	B	A	A	A	A	A	C	F	A	A	A	C
26	Chlorinated rubber	P	4	4	4	4	4	4	4	4	4	4	4	4	4
		S	A	A	A	A	A	A	A	A	A	A	A	A	A
27	Chlorinated rubber	P	2	4	4	3	3	3(1)	3	3	2	4	3	3	3
		S	B	A	A	A	A	A(F)	A	A	B	A	A	A	A
28	Alkyd resind	P	2	4	4	3	4	3	2	2	1	4	3	2	2
		S	B	A	A	A	A	A	B	B	C	A	A	B	B

Note: P = RN of paint film deterioration S = RN of steel corrosion
( ) = data of water leakage area G = G'

Table A9-6 Data of paint film deterioration and steel corrosion of bridges in City G (No.3)
For middle part of the span, Marine environment

No.	Time after repainted (Year, Month)		External girder								Internal girder				
			Exp. J.	U. Flange L. Surface		Web		L. Flange U. Surface		L.F. L.S.	Exp. J.	U.F L.S.	Web	L.F U.S.	L.F L.S
				O.S.	I.S.	O.S.	I.S.	O.S.	I.S.						
21	2.11	P	-	4	4	4	4	-	-	3	-	4	4	-	3
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
22	1.6	P	-	4	4	4	4	-	-	4	-	4	4	-	4
		S	-	A	A	A	A	-	-	A	-	A	A	-	A
23	5.0	P	1	3	3	1	3	3	3	3(1)	-	3	3	3	3
		S	F	A	A	B	A	A	A	A(F)	-	A	A	A	A
24	2.4	P	-	4	4	4	4	4	4	2	-	4	4	4	2
		S	-	A	A	A	A	A	A	B	-	A	A	A	B
25	2.4	P	-	2	4	4	4	4	4	1	-	4	4	4	1
		S	-	B	A	A	A	A	A	C	-	A	A	A	C
26	0.4	P	-	4	4	4	4	4	4	4	-	4	4	4	4
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
27	7.0	P	-	4	4	3	3	3	3	3	-	4	3	3	3
		S	-	A	A	A	A	A	A	A	-	A	A	A	A
28	2.8	P	-	3	3	3	3	-	-	1	-	3	3	-	1
		S	-	A	A	A	A	-	-	C	-	A	A	-	C

Note: P = RN of paint film deterioration　　S = RN of steel corrosion
( ) = data of water leakage area　　G = G'

Table A10-1 Regression equations of paint film deterioration for road bridges in city A, rural environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.16t	0.276t	16	2.0
	P2	4.00 - 0.11t	0.074t	31	6.1
	P4	4.00 - 0.06t	0.062t	36	8.2
	P6	4.00 - 0.09t	0.064t	28	7.0
	P8	4.00 - 0.14t	0.085t	32	5.0
	P14	-	-	-	-
	P15	4.00 - 0.11t	0.068t	35	6.3
	P17	4.00 - 0.09t	0.064t	34	7.1
	P19	4.00 - 0.08t	0.072t	21	6.7
	P21	4.00 - 0.14t	0.099t	33	4.5
Underneath bridge	P3	4.00 - 0.06t	0.068t	34	7.4
	P5	4.00 - 0.09t	0.072t	35	6.6
	P7	4.00 - 0.10t	0.089t	22	5.5
	P9	4.00 - 0.16t	0.108t	9	4.1
	P10	4.00 - 0.09t	0.064t	29	7.2
	P11	4.00 - 0.09t	0.065t	30	7.1
	P12	4.00 - 0.10t	0.107t	18	4.8
	P13	4.00 - 0.12t	0.092t	27	5.0
	P16	4.00 - 0.09t	0.073t	35	6.5
	P18	4.00 - 0.08t	0.078t	37	6.4
	P20	4.00 - 0.12t	0.087t	20	5.3
	P22	-	-	-	-
	P23	4.00 - 0.09t	0.073t	29	6.4
	P24	4.00 - 0.08t	0.068t	31	7.0
	P25	4.00 - 0.06t	0.066t	15	7.6
	P26	4.00 - 0.13t	0.090t	28	5.0

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-2 Regression equations of paint film deterioration for road bridges in city B, marin environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.29t	0.001t	2	6.8
	P2	4.00 - 0.19t	0.006t	6	5.1
	P4	4.00 - 0.20t	0.076t	6	4.7
	P6	-	-	-	-
	P8	4.00 - 0.19t	0.107t	4	3.9
	P14	-	-	-	-
	P15	4.00 - 0.19t	0.066t	6	5.1
	P17	4.00 - 0.19t	0.066t	6	5.1
	P19	-	-	-	-
	P21	4.00 - 0.20t	0.098t	5	4.0
Underneath bridge	P3	4.00 - 0.20t	0.076t	6	4.7
	P5	4.00 - 0.20t	0.076t	6	4.7
	P7	-	-	-	-
	P9	4.00 - 0.29t	0.001t	2	6.8
	P10	4.00 - 0.21t	0.090t	6	4.2
	P11	4.00 - 0.20t	0.076t	6	4.7
	P12	-	-	-	-
	P13	4.00 - 0.31t	0.028t	3	5.1
	P16	4.00 - 0.20t	0.076t	6	4.7
	P18	4.00 - 0.20t	0.076t	6	4.7
	P20	-	-	-	-
	P22	-	-	-	-
	P23	4.00 - 0.21t	0.090t	6	4.2
	P24	4.00 - 0.19t	0.080t	5	4.6
	P25	-	-	-	-
	P26	4.00 - 0.17t	0.115t	3	3.9

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-3 Regression equations of paint film deterioration for road bridges in city B, marine environment, chlorinated rubber

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.13t	0.217t	3	2.6
	P2	4.00 - 0.10t	0.116t	5	4.5
	P4	4.00 - 0.09t	0.101t	7	5.1
	P6	-	-	-	-
	P8	4.00 - 0.15t	0.102t	6	4.4
	P14	-	-	-	-
	P15	4.00 - 0.10t	0.116t	5	4.5
	P17	4.00 - 0.09t	0.090t	7	5.6
	P19	-	-	-	-
	P21	4.00 - 0.03t	0.046t	5	12.2
Underneath bridge	P3	4.00 - 0.03t	0.039t	5	13.4
	P5	4.00 - 0.10t	0.081t	7	5.8
	P7	-	-	-	-
	P9	4.00 - 0.18t	0.073t	3	5.1
	P10	4.00 - 0.03t	0.041t	4	12.7
	P11	4.00 - 0.07t	0.082t	4	6.3
	P12	-	-	-	-
	P13	4.00 - 0.10t	0.123t	4	4.2
	P16	4.00 - 0.10t	0.116t	5	4.5
	P18	4.00 - 0.11t	0.096t	7	5.0
	P20	-	-	-	-
	P22	-	-	-	-
	P23	4.00 - 0.10t	0.123t	4	4.2
	P24	4.00 - 0.10t	0.123t	4	4.2
	P25	-	-	-	-
	P26	-	-	-	-

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-4 Regression equations of paint film deterioration for road bridges in city B, city environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.23t	0.054t	9	5.1
	P2	4.00 - 0.19t	0.075t	18	4.8
	P4	4.00 - 0.17t	0.063t	21	5.6
	P6	4.00 - 0.17t	0.073t	14	5.1
	P8	4.00 - 0.22t	0.065t	15	4.8
	P14	4.00 - 0.16t	0.018t	2	9.4
	P15	4.00 - 0.18t	0.074t	19	5.0
	P17	4.00 - 0.16t	0.068t	21	5.5
	P19	4.00 - 0.16t	0.069t	5	5.4
	P21	4.00 - 0.21t	0.062t	18	5.1
Underneath bridge	P3	4.00 - 0.20t	0.066t	18	5.0
	P5	4.00 - 0.19t	0.057t	19	5.5
	P7	4.00 - 0.14t	0.079t	7	5.4
	P9	4.00 - 0.20t	0.049t	10	5.7
	P10	4.00 - 0.18t	0.059t	19	5.6
	P11	4.00 - 0.17t	0.070t	18	5.2
	P12	4.00 - 0.18t	0.045t	7	6.4
	P13	4.00 - 0.21t	0.054t	14	5.4
	P16	4.00 - 0.20t	0.065t	18	5.0
	P18	4.00 - 0.19t	0.055t	20	5.7
	P20	4.00 - 0.19t	0.043t	3	6.2
	P22	4.00 - 0.16t	0.018t	2	9.4
	P23	4.00 - 0.19t	0.064t	19	5.2
	P24	4.00 - 0.18t	0.061t	17	5.5
	P25	4.00 - 0.20t	0.059t	2	5.3
	P26	4.00 - 0.20t	0.057t	16	5.3

Note: Part Nos. refer to Fig. 3.4   t is Exposure time in year

Table A10-5 Regression equations of paint film deterioration for road bridges in city B, city environment, chlorinated rubber

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.18t	0.111t	7	3.9
	P2	4.00 - 0.11t	0.081t	6	5.6
	P4	4.00 - 0.10t	0.071t	9	6.4
	P6	-	-	-	-
	P8	4.00 - 0.17t	0.076t	9	5.0
	P14	-	-	-	-
	P15	4.00 - 0.11t	0.081t	6	5.6
	P17	4.00 - 0.09t	0.058t	9	7.6
	P19	-	-	-	-
	P21	4.00 - 0.17t	0.084t	8	4.7
Underneath bridge	P3	4.00 - 0.17t	0.132t	5	3.6
	P5	4.00 - 0.15t	0.442t	7	1.4
	P7	-	-	-	-
	P9	4.00 - 0.19t	0.144t	5	3.2
	P10	4.00 - 0.14t	0.105t	4	4.4
	P11	4.00 - 0.15t	0.085t	4	5.0
	P12	-	-	-	-
	P13	4.00 - 0.15t	0.085t	4	5.0
	P16	4.00 - 0.15t	0.101t	5	4.4
	P18	4.00 - 0.12t	0.075t	7	5.8
	P20	-	-	-	-
	P22	-	-	-	-
	P23	4.00 - 0.14t	0.105t	4	4.4
	P24	4.00 - 0.15t	0.085t	4	5.0
	P25	-	-	-	-
	P26	4.00 - 0.15t	0.085t	4	5.0

Note: Part Nos. refer to Fig. 3.4   t is Exposure time in year

Table A10-6 Regression equations of paint film deterioration for road bridges in city C, rural environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.28t	0.140t	9	2.8
	P2	4.00 - 0.13t	0.119t	10	4.1
	P4	4.00 - 0.10t	0.069t	10	6.5
	P6	4.00 - 0.13t	0.122t	6	4.0
	P8	4.00 - 0.18t	0.127t	10	3.6
	P14	-	-	-	-
	P15	4.00 - 0.13t	0.119t	10	4.1
	P17	4.00 - 0.10t	0.069t	10	6.5
	P19	4.00 - 0.13t	0.122t	6	4.0
	P21	4.00 - 0.20t	0.155t	10	3.0
Underneath bridge	P3	4.00 - 0.12t	0.150t	7	3.5
	P5	4.00 - 0.12t	0.099t	10	4.8
	P7	4.00 - 0.10t	0.123t	3	4.3
	P9	4.00 - 0.33t	0.181t	5	2.3
	P10	4.00 - 0.14t	0.143t	7	3.6
	P11	4.00 - 0.14t	0.143t	7	3.6
	P12	4.00 - 0.09t	0.122t	3	4.4
	P13	4.00 - 0.21t	0.134t	7	3.3
	P16	4.00 - 0.12t	0.150t	7	3.5
	P18	4.00 - 0.12t	0.099t	10	4.8
	P20	4.00 - 0.09t	0.091t	4	5.6
	P22	-	-	-	-
	P23	4.00 - 0.14t	0.143t	7	3.6
	P24	4.00 - 0.14t	0.143t	7	3.6
	P25	4.00 - 0.09t	0.122t	3	4.4
	P26	4.00 - 0.25t	0.155t	7	2.8

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-7 Regression equations of paint film deterioration for road bridges in city C, rural environment, chlorinated rubber

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.21t	0.114t	10	3.6
	P2	4.00 - 0.12t	0.101t	13	4.8
	P4	4.00 - 0.08t	0.067t	13	7.2
	P6	4.00 - 0.07t	0.059t	11	8.0
	P8	4.00 - 0.18t	0.225t	13	2.4
	P14	-	-	-	-
	P15	4.00 - 0.12t	0.096t	13	4.9
	P17	4.00 - 0.08t	0.079t	13	6.2
	P19	4.00 - 0.08t	0.070t	9	7.0
	P21	4.00 - 0.16t	0.205t	13	2.6
Underneath bridge	P3	4.00 - 0.09t	0.068t	12	6.8
	P5	4.00 - 0.09t	0.060t	13	7.3
	P7	4.00 - 0.05t	0.048t	9	10.3
	P9	4.00 - 0.22t	0.111t	9	3.6
	P10	4.00 - 0.08t	0.078t	13	6.4
	P11	4.00 - 0.09t	0.071t	13	6.6
	P12	4.00 - 0.07t	0.072t	9	6.9
	P13	4.00 - 0.17t	0.291t	10	1.9
	P16	4.00 - 0.08t	0.056t	12	8.0
	P18	4.00 - 0.10t	0.073t	13	6.2
	P20	4.00 - 0.03t	0.037t	8	13.9
	P22	-	-	-	-
	P23	4.00 - 0.07t	0.058t	12	8.2
	P24	4.00 - 0.12t	0.090t	12	5.2
	P25	4.00 - 0.03t	0.037t	8	13.9
	P26	4.00 - 0.16t	0.220t	12	2.4

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-8 Regression equations of paint film deterioration for road bridges in city D, marine environment, chlorinated rubber

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.19t	0.081t	9	4.6
	P2	4.00 - 0.16t	0.073t	13	5.2
	P4	4.00 - 0.10t	0.028t	15	11.1
	P6	-	-	-	-
	P8	4.00 - 0.20t	0.086t	15	4.4
	P14	-	-	-	-
	P15	4.00 - 0.09t	0.067t	12	6.7
	P17	4.00 - 0.09t	0.063t	14	7.1
	P19	-	-	-	-
	P21	4.00 - 0.16t	0.101t	15	4.3
Underneath bridge	P3	4.00 - 0.10t	0.094t	11	5.2
	P5	4.00 - 0.10t	0.029t	12	10.6
	P7	-	-	-	-
	P9	4.00 - 0.20t	0.075t	7	4.7
	P10	4.00 - 0.08t	0.076t	11	6.5
	P11	4.00 - 0.10t	0.057t	12	7.4
	P12	-	-	-	-
	P13	4.00 - 0.18t	0.080t	12	4.8
	P16	4.00 - 0.07t	0.049t	10	9.3
	P18	4.00 - 0.08t	0.051t	12	8.7
	P20	-	-	-	-
	P22	-	-	-	-
	P23	4.00 - 0.08t	0.062t	10	7.4
	P24	4.00 - 0.07t	0.104t	11	10.5
	P25	-	-	-	-
	P26	4.00 - 0.13t	0.074t	11	5.7

Note: Part Nos. refer to Fig. 3.4   t is Exposure time in year

Table A10-9 Regression equations of paint film deterioration for railway bridges in city E, city environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.24t	0.109t	11	3.5
	P2	4.00 - 0.12t	0.060t	18	6.6
	P3	4.00 - 0.13t	0.086t	15	5.1
	P4	4.00 - 0.12t	0.050t	18	7.4
	P5	4.00 - 0.08t	0.035t	15	10.6
	P6	-	-	-	-
	P7	-	-	-	-
	P8	4.00 - 0.25t	0.087t	17	3.9
	P9	4.00 - 0.24t	0.117t	9	3.4
	P10	4.00 - 0.13t	0.063t	15	6.3
	P11	4.00 - 0.10t	0.039t	15	9.3
	P12	-	-	-	-
	P13	4.00 - 0.24t	0.096t	15	3.8
	P14	-	-	-	-
	P15	4.00 - 0.15t	0.082t	18	5.0
	P16	4.00 - 0.13t	0.062t	16	6.3
	P17	4.00 - 0.12t	0.061t	18	6.6
	P18	4.00 - 0.09t	0.045t	16	9.1
	P19	-	-	-	-
	P20	-	-	-	-
	P21	4.00 - 0.24t	0.096t	17	3.8
	P22	-	-	-	-
	P23	4.00 - 0.15t	0.071t	15	5.4
	P24	4.00 - 0.09t	0.032t	15	10.8
	P25	-	-	-	-
	P26	4.00 - 0.26t	0.096t	15	3.7

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-10 Regression equations of paint film deterioration for railway bridges in city E, rural environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.38t	0.072t	3	3.4
	P2	4.00 - 0.24t	0.078t	12	4.2
	P3	4.00 - 0.22t	0.098t	12	3.9
	P4	4.00 - 0.18t	0.081t	13	4.7
	P5	4.00 - 0.15t	0.065t	12	5.7
	P6	4.00 - 0.23t	0.100t	6	3.7
	P7	4.00 - 0.24t	0.125t	5	3.2
	P8	4.00 - 0.29t	0.134t	13	2.9
	P9	-	-	-	-
	P10	4.00 - 0.22t	0.098t	12	3.9
	P11	4.00 - 0.14t	0.084t	12	5.1
	P12	4.00 - 0.25t	0.215t	4	2.2
	P13	4.00 - 0.27t	0.186t	12	2.4
	P14	-	-	-	-
	P15	4.00 - 0.24t	0.082t	12	4.1
	P16	4.00 - 0.22t	0.098t	12	3.9
	P17	4.00 - 0.18t	0.076t	12	5.0
	P18	4.00 - 0.14t	0.084t	12	5.1
	P19	4.00 - 0.17t	0.058t	6	5.7
	P20	4.00 - 0.20t	0.058t	4	5.4
	P21	4.00 - 0.28t	0.142t	13	2.8
	P22	-	-	-	-
	P23	4.00 - 0.20t	0.076t	12	4.7
	P24	4.00 - 0.17t	0.079t	12	4.9
	P25	4.00 - 0.17t	0.154t	3	3.2
	P26	4.00 - 0.25t	0.161t	13	2.7

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-11 Regression equations of paint film deterioration for road bridges in city F, rural environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.24t	0.189t	25	2.5
	P2	4.00 - 0.12t	0.092t	32	4.1
	P4	4.00 - 0.11t	0.081t	33	5.7
	P6	4.00 - 0.13t	0.093t	26	4.9
	P8	4.00 - 0.16t	0.122t	32	3.8
	P14	-	-	-	-
	P15	4.00 - 0.11t	0.096t	32	5.0
	P17	4.00 - 0.10t	0.076t	33	6.0
	P19	4.00 - 0.12t	0.092t	20	5.0
	P21	4.00 - 0.14t	0.092t	32	4.8
Underneath bridge	P3	4.00 - 0.11t	0.083t	30	5.5
	P5	4.00 - 0.09t	0.078t	31	6.1
	P7	4.00 - 0.12t	0.096t	19	4.9
	P9	4.00 - 0.22t	0.141t	15	3.1
	P10	4.00 - 0.13t	0.094t	25	4.9
	P11	4.00 - 0.09t	0.069t	25	6.8
	P12	4.00 - 0.16t	0.115t	15	4.0
	P13	4.00 - 0.18t	0.123t	25	3.7
	P16	4.00 - 0.11t	0.085t	30	5.5
	P18	4.00 - 0.09t	0.069t	31	6.7
	P20	4.00 - 0.17t	0.129t	13	3.6
	P22	-	-	-	-
	P23	4.00 - 0.11t	0.091t	24	5.2
	P24	4.00 - 0.10t	0.078t	24	6.0
	P25	4.00 - 0.14t	0.119t	10	4.0
	P26	4.00 - 0.18t	0.101t	25	4.2

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-12 Regression equations of paint film deterioration for road bridges in city G, marine environment, alkyd resins

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.29t	0.216t	6	1.6
	P2	4.00 - 0.21t	0.172t	8	2.8
	P4	4.00 - 0.15t	0.153t	8	3.3
	P6	4.00 - 0.14t	0.104t	6	4.5
	P8	4.00 - 0.30t	0.294t	7	1.7
	P14	-	-	-	-
	P15	4.00 - 0.22t	0.169t	8	2.8
	P17	4.00 - 0.16t	0.192t	8	2.7
	P19	4.00 - 0.13t	0.076t	5	5.6
	P21	4.00 - 0.30t	0.336t	7	1.5
Underneath bridge	P3	4.00 - 0.20t	0.129t	8	3.4
	P5	4.00 - 0.20t	0.129t	8	3.4
	P7	4.00 - 0.18t	0.192t	5	2.6
	P9	4.00 - 0.38t	0.482t	5	1.1
	P10	4.00 - 0.20t	0.129t	8	3.4
	P11	4.00 - 0.22t	0.169t	8	2.8
	P12	4.00 - 0.18t	0.192t	5	2.6
	P13	4.00 - 0.31t	0.245t	7	1.9
	P16	4.00 - 0.21t	0.129t	8	3.4
	P18	4.00 - 0.22t	0.169t	8	2.8
	P20	4.00 - 0.16t	0.086t	4	4.8
	P22	-	-	-	-
	P23	4.00 - 0.21t	0.129t	8	3.4
	P24	4.00 - 0.23t	0.209t	8	2.3
	P25	4.00 - 0.16t	0.086t	4	4.8
	P26	4.00 - 0.32t	0.300t	7	1.9

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A10-13 Regression equations of paint film deterioration for road bridges in city G, marine environment, chlorinated rubber

Condition	Part No.	Regression Eq. RN	Standard deviation SD	Number of data	Service life (year)
Exposed to rain	P1	4.00 - 0.29t	0.210t	13	2.2
	P2	4.00 - 0.25t	0.213t	16	2.3
	P4	4.00 - 0.23t	0.182t	16	2.6
	P6	4.00 - 0.09t	0.115t	10	4.6
	P8	4.00 - 0.28t	0.268t	16	1.8
	P14	-	-	-	-
	P15	4.00 - 0.18t	0.171t	16	2.9
	P17	4.00 - 0.18t	0.164t	16	3.0
	P19	4.00 - 0.07t	0.081t	9	6.4
	P21	4.00 - 0.24t	0.250t	16	2.0
Underneath bridge	P3	4.00 - 0.17t	0.145t	13	3.3
	P5	4.00 - 0.16t	0.140t	16	3.5
	P7	4.00 - 0.04t	0.055t	9	9.6
	P9	4.00 - 0.27t	0.181t	12	2.5
	P10	4.00 - 0.11t	0.104t	12	4.8
	P11	4.00 - 0.14t	0.135t	15	3.6
	P12	4.00 - 0.04t	0.055t	9	9.6
	P13	4.00 - 0.24t	0.250t	15	2.0
	P16	4.00 - 0.13t	0.125t	13	3.9
	P18	4.00 - 0.14t	0.126t	16	3.9
	P20	4.00 - 0.04t	0.056t	8	9.4
	P22	-	-	-	-
	P23	4.00 - 0.04t	0.050t	11	10.5
	P24	4.00 - 0.12t	0.126t	14	4.0
	P25	4.00 - 0.04t	0.056t	8	9.4
	P26	4.00 - 0.24t	0.277t	14	1.9

Note: Part Nos. refer to Fig. 3.4 t is Exposure time in year

Table A11-1 Paint history of bridges in city A, rural environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
A1	A	2- 6-1989	10-1933	( )	3-1974	-	-
A2	A	2- 6-1989	8-1983	-	-	-	-
A3	A	2- 6-1989	11-1959	11-1976	-	-	-
A4	A	2- 6-1989	1953	3-1979	-	-	-
A5	A	3- 6-1989	(12-1986)	-	-	-	-
A6	A	3- 6-1989	10-1932	( )	3-1981	-	-
A7	A	3- 6-1989	10-1943	5-1961	-	-	-
A8	A	4- 6-1989	9-1938	( )	3-1980	-	-
A9	A	4- 6-1989	11-1976	-	-	-	-
A10	A	4- 6-1989	(8-1974)	-	-	-	-
A11	A	4- 6-1989	3-1986	-	-	-	-
A12	A	4- 6-1989	1-1962	3-1983	-	-	-
A13	A	4- 6-1989	9-1970	-	-	-	-
A14	A	4- 6-1989	5-1970	3-1982	-	-	-
A15	A	5- 6-1989	12-1988	-	-	-	-
A16	A	5- 6-1989	(11-1965)	-	-	-	-
A17	A	5- 6-1989	2-1963	3-1988	-	-	-
A18	A	7- 6-1989	3-1958	1-1980	-	-	-
A19	A	7- 6-1989	9-1952	2-1972	-	-	-
A20	A	7- 6-1989	12-1963	11-1981	-	-	-
A21	A	7- 6-1989	3-1973	12-1981	-	-	-
A22	A	7- 6-1989	3-1980	-	-	-	-
A23	A	1- 7-1989	5-1934	-	-	-	-
A24	A	1- 7-1989	3-1973	-	-	-	-
A25	A	1- 7-1989	3-1964	1-1987	-	-	-
A26	A	1- 7-1989	3-1973	3-1983	-	-	-
A27	A	1- 7-1989	(12-1981)	-	-	-	-
A28	A	1- 7-1989	7-1960	3-1982	-	-	-
A29	A	1- 7-1989	5-1952	( )	7-1981	-	-
A30	A	7- 7-1989	3-1962	-	-	-	-
A31	A	7- 7-1989	3-1975	3-1987	-	-	-
A32	A	7- 7-1989	5-1957	4-1966	-	-	-
A33	A	7- 7-1989	10-1964	-	-	-	-
A34	A	7- 7-1989	3-1961	2-1977	-	-	-
A35	A	7- 7-1989	1-1974	-	-	-	-
A36	A	8- 7-1989	6-1961	( )	11-1981	-	-
A37	A	8- 7-1989	4-1984	-	-	-	-
A38	A	8- 7-1989	3-1982	-	-	-	-
A39	A	8- 7-1989	12-1968	-	-	-	-
A40	A	8- 7-1989	10-1982	-	-	-	-
A41	A	8- 7-1989	(3-1981)	-	-	-	-
A42	A	8- 7-1989	3-1975	10-1984	-	-	-

Note; A : Alkyd resins

Table A11-2 Paint history of bridges in city B, marine environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
B1	C	31- 8-1989	11-1938	1966	3-1979	-	-
B2	A	31- 8-1989	11-1938	1963	3-1979	-	-
B3	(A)	31- 8-1989	11-1965	-	-	-	-
B4	A	31- 8-1989	3-1964	3-1979	-	-	-
B5	C	31- 8-1989	12-1982	-	-	-	-
B11	(A)	31- 8-1989	1-1936	2-1971	-	-	-
B12	A	31- 8-1989	9-1939	1971	2-1979	-	-
B13	A	31- 8-1989	3-1966	-	-	-	-
B15	(A)	31- 8-1989	10-1968	-	-	-	-
B16	C	31- 8-1989	1-1988	-	-	-	-
B18	C	31- 8-1989	3-1961	1976	8-1985	-	-
B19	A	31- 8-1989	11-1963	-	-	-	-
B20	(A)	8- 9-1989	10-1973	-	-	-	-
B21	C	8- 9-1989	7-1977	-	-	-	-
B22	(A)	8- 9-1989	3-1958	3-1978	-	-	-
B23	A	8- 9-1989	3-1963	5-1979	-	-	-
B24	(A)	8- 9-1989	3-1963	-	-	-	-
B25	-	8- 9-1989	8-1959	1979	4-1989	-	-
B26	(A)	8- 9-1989	4-1959	-	-	-	-
B27	A	8- 9-1989	4-1981	-	-	-	-
B34	C	8- 9-1989	3-1983	-	-	-	-
B35	C	8- 9-1989	4-1964	-	-	-	-

Note; A : Alkyd resins C : Chlorinated rubber

Table A11-3 Paint history of bridges in city B, city environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
B36	A	9- 9-1989	0-1963	3-1974)	-	-	-
B37	(A)	9- 9-1989	3-1971	-	-	-	-
B38	C	9- 9-1989	9-1962	4-1984	-	-	-
B39	C	9- 9-1989	3-1989	-	-	-	-
B40	A	9- 9-1989	3-1965	8-1974	-	-	-
B41	C	10- 9-1989	1-1973	-	-	-	-
B42	(A)	10- 9-1989	4-1970	-	-	-	-
B43	C	10- 9-1989	3-1977	-	-	-	-
B44	C	10- 9-1989	1969	-	-	-	-
B45	A	10- 9-1989	11-1956	3-1979	-	-	-

Note; A : Alkyd resins C : Chlorinated rubber

Table A11-3 Continue

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
B46	A	10- 9-1989	3-1961	3-1979	-	-	-
B47	(A)	10- 9-1989	3-1967	-	-	-	-
B48	A	10- 9-1989	3-1965	3-1979	-	-	-
B49	A	10- 9-1989	3-1961	3-1979	-	-	-
B50	A	10- 9-1989	1951	3-1979	-	-	-
B51	A	10- 9-1989	3-1964	3-1979	-	-	-
B52	A	10- 9-1989	11-1937	3-1974	-	-	-
B53	A	10- 9-1989	3-1972	3-1974	-	-	-
B56	C	11- 9-1989	3-1970	-	-	-	-
B57	C	11- 9-1989	12-1935	1963	1973	3-1988	-
B58	(A)	11- 9-1989	1-1924	1954	11-1971	-	-
B59	A	11- 9-1989	10-1935	1959	11-1971	-	-
B63	A	25- 9-1989	3-1962	3-1973	-	-	-
B64	(A)	25- 9-1989	4-1932	1964	3-1979	-	-
B65	-	25- 9-1989	3-1986	-	-	-	-
B66	(A)	25- 9-1989	1955	2-1971	-	-	-
B67	(A)	25- 9-1989	1-1957	3-1979	-	-	-
B68	(A)	25- 9-1989	2-1931	1965	4-1979	-	-
B69	(A)	9- 9-1989	10-1956	1968	5-1979	-	-
B70	A	9- 9-1989	1-1960	3-1979	-	-	-
B71	A	9- 9-1989	3-1968	3-1979	-	-	-
B72	(A)	9- 9-1989	10-1960	5-1979	-	-	-
B73	A	9- 9-1989	1936	1963	3-1972	-	-
B74	A	9- 9-1989	9-1936	1959	10-1972	-	-
B75	(A)	9- 9-1989	3-1973	-	-	-	-
B76	A	9- 9-1989	3-1964	3-1979	-	-	-
B78	A	9- 9-1989	8-1973	-	-	-	-
B79	C	9- 9-1989	3-1973	2-1985	-	-	-
B80	A	8- 9-1989	3-1973	3-1982	-	-	-
B81	A	8- 9-1989	8-1969	7-1979	-	-	-
B82	(A)	8- 9-1989	3-1965	-	-	-	-
B83	(A)	8- 9-1989	3-1972	-	-	-	-
B84	(A)	10- 9-1989	3-1968	-	-	-	-
B85	A	10- 9-1989	5-1954	3-1969	-	-	-
B86	C	10- 9-1989	12-1979	-	-	-	-
B87	(A)	10- 9-1989	1927	1964	5-1970	-	-
B88	(A)	10- 9-1989	3-1978	-	-	-	-
B89	A	10- 9-1989	1-1976	2-1975	-	-	-

Note; A : Alkyd resins C : Chlorinated rubber

Table A11-4 Paint history of bridges in city C, rural environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
C1	A	17-10-1989	11-1968	( )	3-1989	-	-
C2	C	17-10-1989	10-1956	( )	1-1985	-	-
C3	C	17-10-1989	11-1977	12-1988	-	-	-
C4	C	17-10-1989	7-1973	-	-	-	-
C5	C	17-10-1989	3-1989	-	-	-	-
C6	C	17-10-1989	3-1980	-	-	-	-
C7	C	17-10-1989	9-1982	-	-	-	-
C8	C	17-10-1989	(12-1982)	-	-	-	-
C9	C	17-10-1989	10-1984	-	-	-	-
C10	A	17-10-1989	(6-1976)	-	-	-	-
C11	C	17-10-1989	3-1986	-	-	-	-
C12	C	17-10-1989	(1-1978)	-	-	-	-
C13	A	17-10-1989	10-1963	12-1983	-	-	-
C14	C	17-10-1989	1955	2-1981	-	-	-
C15	A	17-10-1989	(12-1986)	-	-	-	-
C16	A	17-10-1989	3-1972	10-1984	-	-	-
C17	A	17-10-1989	10-1967	2-1984	-	-	-
C18	A	17-10-1989	(9-1981)	-	-	-	-
C19	P	17-10-1989	1-1981	-	-	-	-
C20	C	17-10-1989	12-1978	-	-	-	-
C21	C	17-10-1989	(3-1977)	-	-	-	-
C22	A	17-10-1989	3-1978	-	-	-	-
C23	A	17-10-1989	3-1979	-	-	-	-
C24	A	17-10-1989	3-1981	-	-	-	-

Note; A : Alkyd resins C : Chlorinated rubber P : Polyurethane resins

Table A11-5 Paint history of bridges in city D, marine environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
D1	C	26-12-1989	7-1968	3-1976	-	-	-
D2	C	26-12-1989	7-1968	2-1978	-	-	-
D3	C	26-12-1989	7-1968	2-1977	-	-	-
D4	C	26-12-1989	7-1968	4-1980	-	-	-
D5	C	26-12-1989	7-1968	2-1977	-	-	-
D6	C	26-12-1989	7-1968	2-1988	-	-	-
D7	C	26-12-1989	3-1965	2-1979	-	-	-
D8	C	26-12-1989	3-1965	2-1981	-	-	-
D9	C	26-12-1989	10-1966	2-1977	-	-	-
D10	C	26-12-1989	7-1966	2-1979	-	-	-
D11	C	6-12-1989	(7-1980)	-	-	-	-
D12	C	6-12-1989	(7-1980)	-	-	-	-
D13	C	6-12-1989	10-1978	-	-	-	-
D14	C	6-12-1989	10-1978	-	-	-	-
D15	C	6-12-1989	8-1980	-	-	-	-
D16	C	6-12-1989	3-1982	-	-	-	-

Note; C : Chlorinated rubber

Table A11-6 Paint history of bridges in city E, city environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
E1	A	27-12-1989	11-1970	8-1981	-	-	-
E2	A	27-12-1989	11-1970	3-1980	-	-	-
E6	A	27-12-1989	11-1970	3-1982	-	-	-
E7	C	27-12-1989	11-1970	7-1983	-	-	-
E8	A	27-12-1989	11-1970	3-1980	-	-	-
E9	A	27-12-1989	12-1933	( )	( )	1976	9-1989
E10	A	27-12-1989	12-1933	( )	( )	1976	9-1989
E11	A	27-12-1989	12-1933	( )	( )	11-1977	-
E14	A	27-12-1989	12-1933	( )	( )	10-1976	-
E16	A	27-12-1989	12-1933	( )	( )	1977	9-1989
E17	A	27-12-1989	12-1933	( )	( )	3-1977	-
E18	A	27-12-1989	12-1933	( )	( )	1975	9-1989
E20	A	27-12-1989	6-1937	( )	( )	2-1979	-
E23	A	27-12-1989	12-1933	( )	( )	11-1977	-
E24	A	27-12-1989	8-1933	( )	( )	1969	3-1981
E25	A	27-12-1989	8-1933	( )	( )	11-1977	-
E26	A	28-12-1989	8-1933	( )	( )	3-1977	-
E27	A	28-12-1989	8-1933	( )	( )	12-1976	-
E28	A	28-12-1989	8-1933	( )	( )	9-1979	-

Note; A : Alkyd resins

Table A11-7 Paint history of bridges in city E, rural environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
E32	A	28-12-1989	12-1972	11-1988	-	-	-
E34	A	28-12-1989	7-1931	( )	( )	4-1978	-
E35	A	28-12-1989	7-1931	( )	( )	1972	2-1982
E40	A	28-12-1989	3-1973	4-1986	-	-	-
E41	A	28-12-1989	3-1973	12-1978	-	-	-
E42	A	28-12-1989	1927	( )	( )	1971	3-1983
E43	A	28-12-1989	1928	( )	( )	4-1978	-
E44	A	28-12-1989	1927	( )	( )	1971	3-1981
E46	A	29-12-1989	1928	( )	( )	1972	3-1986
E47	A	29-12-1989	1926	( )	( )	1971	11-1984
E48	A	29-12-1989	1926	( )	( )	1970	3-1980
E49	A	29-12-1989	1928	( )	( )	1970	3-1980
E51	A	29-12-1989	1928	( )	( )	8-1978	-
E52	A	29-12-1989	1928	( )	( )	7-1978	-
E53	C	29-12-1989	1928	( )	( )	1970	9-1983

Note; A : Alkyd resins

Table A11-8 Paint history of bridges in city F, mountainous environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
B1	C	21- 5-1989	3-1974	-	-	-	-
B2	A	21- 5-1989	3-1968	12-1979	-	-	-
B3	A	22- 5-1989	12-1982	-	-	-	-
B4	A	22- 5-1989	6-1969	1977	12-1987	-	-
B5	A	22- 5-1989	3-1960	2-1979	-	-	-
B6	A	22- 5-1989	3-1979	-	-	-	-
B7	A	22- 5-1989	3-1981	-	-	-	-
B8	A	22- 5-1989	8-1966	1978	12-1988	-	-
B9	A	22- 5-1989	11-1969	9-1980	-	-	-
B10	A	22- 5-1989	12-1971	2-1990	-	-	-
B11	A	22- 5-1989	12-1989	-	-	-	-
B12	A	23- 5-1989	5-1977	5 1986	-	-	-
B13	A	23- 5-1989	3-1973	11-1986	-	-	-
B14	A	23- 5-1989	3-1978	-	-	-	-
B15	A	23- 5-1989	2-1975	10-1987	-	-	-
B16	A	23- 5-1989	12-1966	1979	12-1986	-	-
B17	A	23- 5-1989	3-1971	9-1979	-	-	-
B18	A	23- 5-1989	6-1983	-	-	-	-
B19	A	23- 5-1989	3-1987	-	-	-	-
B20	A	23- 5-1989	11-1979	-	-	-	-
B21	A	23- 5-1989	11-1979	-	-	-	-
B22	A	23- 5-1989	6-1973	6-1987	-	-	-
B23	A	23- 5-1989	11-1976	-	-	-	-
B24	A	23- 5-1989	11-1976	10-1987	-	-	-
B25	A	24- 5-1989	3-1979	-	-	-	-
B26	A	22- 5-1989	8-1972	-	-	-	-
B27	A	22- 5-1989	3-1989	-	-	-	-
B28	A	22- 5-1989	(11-1989)	-	-	-	-
B29	A	22- 5-1989	7-1975	-	-	-	-
B30	A	21- 5-1989	10-1985	-	-	-	-
B31	A	22- 5-1989	11-1979	-	-	-	-
B32	A	23- 5-1989	1960	-	-	-	-
B33	A	23- 5-1989	3-1974	-	-	-	-
B34	A	24- 5-1989	(1981)	-	-	-	-
B35	-	21- 5-1989	( )	-	-	-	-
B36	-	21- 5-1989	( )	-	-	-	-

Note; A : Alkyd resins C : Chlorinated rubber

Table A11-9 Paint history of bridges in city G, marine environment

Bridge No.	Paint type	Surveying date	Paint history				
			1st paint	Repaint 1	Repaint 2	Repaint 3	Repaint 4
G1	C	10- 6-1989	9-1987	-	-	-	-
G2	A	10- 6-1989	4-1975	8-1979	-	-	-
G3	E	10- 6-1989	4-1975	2-1982	-	-	-
G4	C	10- 6-1989	6-1975	2-1983	-	-	-
G5	C	10- 6-1989	3-1987	-	-	-	-
G6	C	10- 6-1989	3-1987	-	-	-	-
G7	A	10- 6-1989	3-1975	10-1979	-	-	-
G8	A	10- 6-1989	3-1973	2-1979	1986	-	-
G9	C	10- 6-1989	3-1980	-	-	-	-
G10	A	10- 6-1989	11-1976	3-1990	-	-	-
G11	C	11- 6-1989	7-1987	-	-	-	-
G12	A	11- 6-1989	12-1970	1977	12-1988	-	-
G13	C	11- 6-1989	1-1986	-	-	-	-
G14	P	12- 6-1989	12-1976	3-1989	-	-	-
G15	A	12- 6-1989	3-1986	-	-	-	-
G16	A	12- 6-1989	1-1984	-	-	-	-
G17	C	12- 6-1989	3-1975	11-1981	-	-	-
G18	C	12- 6-1989	3-1975	11-1981	-	-	-
G19	E	12- 6-1989	2-1985	-	-	-	-
G20	C	12- 6-1989	3-1985	-	-	-	-
G21	A	11- 6-1989	7-1987	-	-	-	-
G22	C	10- 6-1989	10-1983	12-1988	-	-	-
G23	C	12- 6-1989	11-1962	3-1973	3-1978	1-1985	-
G24	C	13- 6-1989	6-1975	2-1983	2-1988	-	-
G25	C	13- 6-1989	6-1975	2-1982	2-1988	-	-
G26	C	13- 6-1989	6-1975	2-1984	2-1990	-	-
G27	-	13- 6-1989	1953	1977	6-1983	-	-
G28	A	13- 6-1989	9-1974	12-1982	10-1987	-	-

Note; A : Alkyd resins C : Chlorinated rubber
E : Expoxy resins P : Polyurethane resins

Table A12-1 Results of the determined relation between corrosion depth and exposure time for bridges in city A, rural environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.062	0.813	-	-	0.059	0.799
	P2	0.023	0.816	-	-	0.024	0.793
	P4	0.030	0.685	-	-	0.029	0.644
	P6	0.024	0.747	-	-	0.022	0.701
	P8	0.029	0.818	-	-	0.026	0.773
	P14	-	-	-	-	-	-
	P15	0.022	0.786	-	-	0.020	0.757
	P17	0.026	0.703	-	-	0.026	0.698
	P19	0.035	0.732	-	-	0.033	0.725
	P21	0.022	0.818	-	-	0.022	0.795
Underneath bridges	P3	0.019	0.711	-	-	0.020	0.705
	P5	0.029	0.749	-	-	0.028	0.713
	P7	0.033	0.841	-	-	0.028	0.764
	P9	0.087	0.832	-	-	0.068	0.707
	P10	0.021	0.747	-	-	0.021	0.780
	P11	0.027	0.739	-	-	0.024	0.702
	P12	0.020	0.745	-	-	0.024	0.806
	P13	0.025	0.777	-	-	0.025	0.749
	P16	0.024	0.771	-	-	0.024	0.756
	P18	0.018	0.673	-	-	0.020	0.700
	P20	0.032	0.895	-	-	0.030	0.840
	P22	-	-	-	-	-	-
	P23	0.021	0.715	-	-	0.021	0.705
	P24	0.016	0.708	-	-	0.018	0.744
	P25	0.036	0.796	-	-	0.037	0.785
	P26	0.024	0.794	-	-	0.022	0.753

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-2 Results of the determined relation between corrosion depth and exposure time for bridges in city B, marine environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.036	0.861	0.037	0.881	-	-
	P2	0.045	0.630	0.043	0.579	-	-
	P4	0.033	0.592	0.035	0.609	-	-
	P6	0.050	0.849	0.034	0.755	-	-
	P8	0.049	0.659	0.050	0.672	-	-
	P14	-	-	0.028	0.714	-	-
	P15	0.043	0.600	0.043	0.591	-	-
	P17	0.035	0.616	0.035	0.596	-	-
	P19	-	-	-	-	-	-
	P21	0.074	0.740	0.064	0.688	-	-
Underneath bridges	P3	0.040	0.812	0.032	0.734	-	-
	P5	0.039	0.687	0.038	0.635	-	-
	P7	0.050	0.849	0.034	0.755	-	-
	P9	0.083	0.912	0.060	0.757	-	-
	P10	0.036	0.744	0.033	0.708	-	-
	P11	0.051	0.695	0.047	0.606	-	-
	P12	-	-	-	-	-	-
	P13	0.054	0.674	0.053	0.668	-	-
	P16	0.042	0.599	0.044	0.608	-	-
	P18	0.035	0.626	0.037	0.648	-	-
	P20	-	-	-	-	-	-
	P22	-	-	0.028	0.714	-	-
	P23	0.046	0.602	0.046	0.587	-	-
	P24	0.042	0.591	0.044	0.606	-	-
	P25	-	-	-	-	-	-
	P26	0.051	0.845	0.044	0.802	-	-

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-3 Results of the determined relation between corrosion depth and exposure time for bridges in city B, city environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.056	0.850	0.065	0.770	-	-
	P2	0.036	0.391	0.046	0.460	-	-
	P4	0.031	0.366	0.038	0.455	-	-
	P6	0.021	0.664	0.027	0.668	-	-
	P8	0.041	0.805	0.041	0.721	-	-
	P14	0.048	0.840	0.036	0.779	-	-
	P15	0.036	0.392	0.045	0.453	-	-
	P17	0.025	0.392	0.031	0.516	-	-
	P19	0.021	0.660	0.023	0.675	-	-
	P21	0.038	0.797	0.036	0.717	-	-
Underneath bridges	P3	0.031	0.738	0.029	0.687	-	-
	P5	0.025	0.564	0.031	0.621	-	-
	P7	0.039	0.801	0.042	0.782	-	-
	P9	0.035	0.751	0.034	0.767	-	-
	P10	0.028	0.608	0.034	0.610	-	-
	P11	0.033	0.403	0.047	0.454	-	-
	P12	0.024	0.686	0.036	0.777	-	-
	P13	0.033	0.759	0.037	0.715	-	-
	P16	0.029	0.731	0.029	0.694	-	-
	P18	0.030	0.450	0.036	0.536	-	-
	P20	-	-	0.031	0.727	-	-
	P22	-	-	0.041	0.809	-	-
	P23	0.028	0.604	0.034	0.603	-	-
	P24	0.024	0.570	0.033	0.577	-	-
	P25	-	-	0.030	0.721	-	-
	P26	0.036	0.777	0.037	0.689	-	-

Note; $Y = k\ t^m$
Y : Maximum corrosion depth (mm)
t : Accumulated exposure time of steel surface after paint life (year)
Part Nos. refer to Fig. 3.4

Table A12-4 Results of the determined relation between corrosion depth and exposure time for bridges in city C, rural environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.039	0.814	-	-	0.059	0.799
	P2	0.016	0.253	-	-	0.024	0.793
	P4	0.017	0.279	-	-	0.029	0.644
	P6	0.019	0.313	-	-	0.022	0.701
	P8	0.025	0.414	-	-	0.026	0.773
	P14	-	-	-	-	-	-
	P15	0.016	0.258	-	-	0.020	0.757
	P17	0.016	0.279	-	-	0.026	0.698
	P19	0.024	0.350	-	-	0.033	0.725
	P21	0.022	0.475	-	-	0.022	0.795
Underneath bridges	P3	0.016	0.301	-	-	0.018	0.407
	P5	0.016	0.296	-	-	0.017	0.336
	P7	-	-	-	-	-	-
	P9	0.041	0.631	-	-	0.042	0.660
	P10	0.017	0.328	-	-	0.019	0.425
	P11	0.020	0.311	-	-	0.022	0.383
	P12	0.029	0.457	-	-	0.029	0.457
	P13	0.032	0.560	-	-	0.032	0.553
	P16	0.017	0.336	-	-	0.019	0.421
	P18	0.015	0.287	-	-	0.016	0.361
	P20	-	-	-	-	-	-
	P22	-	-	-	-	-	-
	P23	0.017	0.345	-	-	0.019	0.430
	P24	0.018	0.320	-	-	0.020	0.404
	P25	-	-	-	-	-	-
	P26	0.023	0.484	-	-	0.020	0.607

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-5 Results of the determined relation between corrosion depth and exposure time for bridges in city D, marine environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.032	0.744	0.025	0.653	-	-
	P2	0.021	0.628	0.021	0.626	-	-
	P4	-	-	-	-	-	-
	P6	-	-	-	-	-	-
	P8	0.034	0.730	0.029	0.664	-	-
	P14	-	-	-	-	-	-
	P15	0.038	0.786	0.038	0.786	-	-
	P17	0.043	0.788	0.037	0.732	-	-
	P19	-	-	-	-	-	-
	P21	0.066	0.903	0.045	0.753	-	-
Underneath bridges	P3	0.018	0.594	0.018	0.594	-	-
	P5	-	-	-	-	-	-
	P7	-	-	-	-	-	-
	P9	0.036	0.774	0.024	0.637	-	-
	P10	0.036	0.776	0.036	0.776	-	-
	P11	0.051	0.852	0.051	0.852	-	-
	P12	-	-	-	-	-	-
	P13	0.059	0.879	0.038	0.727	-	-
	P16	-	-	-	-	-	-
	P18	0.018	0.624	0.018	0.624	-	-
	P20	-	-	-	-	-	-
	P22	-	-	-	-	-	-
	P23	0.044	0.814	0.044	0.814	-	-
	P24	-	-	-	-	-	-
	P25	-	-	-	-	-	-
	P26	0.045	0.725	0.045	0.725	-	-

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-6 Results of the determined relation between corrosion depth and exposure time for bridges in city E, city environment.

Condition	Part	Data class 1		Data class 2		Data class 3	
	No.	k	m	k	m	k	m
Exposed to rain	P1	-	-	-	-	0.029	0.668
	P2	-	-	-	-	0.019	0.615
	P3	-	-	-	-	0.016	0.580
	P4	-	-	-	-	0.018	0.587
	P5	-	-	-	-	-	-
	P6	-	-	-	-	-	-
	P7	-	-	-	-	-	-
	P8	-	-	-	-	0.023	0.597
	P9	-	-	-	-	0.023	0.668
	P10	-	-	-	-	0.016	0.573
	P11	-	-	-	-	0.017	0.612
	P12	-	-	-	-	-	-
	P13	-	-	-	-	0.023	0.636
	P14	-	-	-	-	-	-
	P15	-	-	-	-	0.017	0.616
	P16	-	-	-	-	0.014	0.576
	P17	-	-	-	-	0.017	0.576
	P18	-	-	-	-	0.016	0.608
	P19	-	-	-	-	-	-
	P20	-	-	-	-	-	-
	P21	-	-	-	-	0.023	0.596
	P22	-	-	-	-	-	-
	P23	-	-	-	-	0.017	0.599
	P24	-	-	-	-	-	-
	P25	-	-	-	-	-	-
	P26	-	-	-	-	0.024	0.619

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-7 Results of the determined relation between corrosion depth and exposure time for bridges in city E, rural environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	-	-	-	-	0.029	0.729
	P2	-	-	-	-	0.014	0.569
	P3	-	-	-	-	0.013	0.549
	P4	-	-	-	-	0.014	0.577
	P5	-	-	-	-	0.021	0.665
	P6	-	-	-	-	0.015	0.583
	P7	-	-	-	-	0.016	0.600
	P8	-	-	-	-	0.015	0.543
	P9	-	-	-	-	0.043	0.819
	P10	-	-	-	-	0.013	0.549
	P11	-	-	-	-	0.017	0.609
	P12	-	-	-	-	0.022	0.674
	P13	-	-	-	-	0.015	0.572
	P14	-	-	-	-	-	-
	P15	-	-	-	-	0.013	0.552
	P16	-	-	-	-	0.013	0.549
	P17	-	-	-	-	0.015	0.587
	P18	-	-	-	-	0.021	0.659
	P19	-	-	-	-	0.021	0.660
	P20	-	-	-	-	0.013	0.556
	P21	-	-	-	-	0.015	0.543
	P22	-	-	-	-	-	-
	P23	-	-	-	-	0.013	0.555
	P24	-	-	-	-	0.015	0.582
	P25	-	-	-	-	0.012	0.547
	P26	-	-	-	-	0.014	0.553

Note; $Y = k\,t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-8 Results of the determined relation between corrosion depth and exposure time for bridges in city F, mountainous environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.028	0.969	0.028	0.901	-	-
	P2	0.020	0.453	0.020	0.488	-	-
	P4	0.013	0.288	0.014	0.346	-	-
	P6	0.026	0.464	0.026	0.494	-	-
	P8	0.026	0.561	0.026	0.581	-	-
	P14	-	-	-	-	-	-
	P15	0.018	0.386	0.019	0.442	-	-
	P17	0.013	0.297	0.014	0.355	-	-
	P19	0.043	0.583	0.040	0.536	-	-
	P21	0.026	0.505	0.026	0.501	-	-
Underneath bridges	P3	0.017	0.365	0.017	0.431	-	-
	P5	0.014	0.307	0.015	0.411	-	-
	P7	0.029	0.444	0.031	0.491	-	-
	P9	0.057	0.693	0.055	0.667	-	-
	P10	0.018	0.350	0.019	0.450	-	-
	P11	0.016	0.285	0.017	0.331	-	-
	P12	0.032	0.482	0.034	0.517	-	-
	P13	0.024	0.471	0.024	0.510	-	-
	P16	0.017	0.365	0.017	0.405	-	-
	P18	0.015	0.315	0.016	0.372	-	-
	P20	0.045	0.655	0.040	0.607	-	-
	P22	-	-	-	-	-	-
	P23	0.016	0.286	0.017	0.391	-	-
	P24	0.014	0.281	0.015	0.374	-	-
	P25	0.046	0.668	0.046	0.668	-	-
	P26	0.024	0.475	0.024	0.510	-	-

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

Table A12-9 Results of the determined relation between corrosion depth and exposure time for bridges in city G, marine environment.

Condition	Part No.	Data class 1		Data class 2		Data class 3	
		k	m	k	m	k	m
Exposed to rain	P1	0.087	0.932	0.095	0.838	-	-
	P2	0.042	0.781	0.042	0.712	-	-
	P4	0.042	0.848	0.035	0.762	-	-
	P6	-	-	0.026	0.700	-	-
	P8	0.067	0.906	0.064	0.765	-	-
	P14	-	-	-	-	-	-
	P15	0.042	0.781	0.041	0.710	-	-
	P17	0.025	0.628	0.030	0.674	-	-
	P19	-	-	0.026	0.700	-	-
	P21	0.058	0.812	0.066	0.716	-	-
Underneath bridges	P3	0.051	0.764	0.043	0.708	-	-
	P5	0.036	0.790	0.033	0.746	-	-
	P7	-	-	0.037	0.732	-	-
	P9	0.075	0.974	0.093	0.879	-	-
	P10	0.031	0.704	0.030	0.697	-	-
	P11	0.026	0.702	0.031	0.758	-	-
	P12	-	-	0.037	0.732	-	-
	P13	0.053	0.892	0.063	0.815	-	-
	P16	0.032	0.610	0.032	0.616	-	-
	P18	0.025	0.628	0.028	0.670	-	-
	P20	-	-	0.031	0.701	-	-
	P22	-	-	-	-	-	-
	P23	-	-	0.030	0.697	-	-
	P24	-	-	0.035	0.788	-	-
	P25	-	-	0.031	0.701	-	-
	P26	0.055	0.904	0.072	0.850	-	-

Note; $Y = k\ t^m$

Y : Maximum corrosion depth (mm)

t : Accumulated exposure time of steel surface after paint life (year)

Part Nos. refer to Fig. 3.4

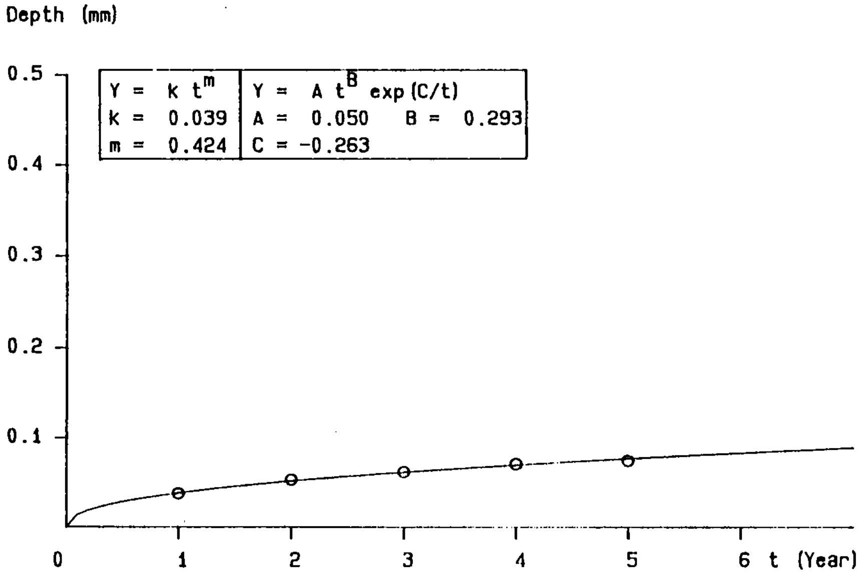

Fig. A1-E1 Long-term corrosion of bare steel exposed to rain
Otaru

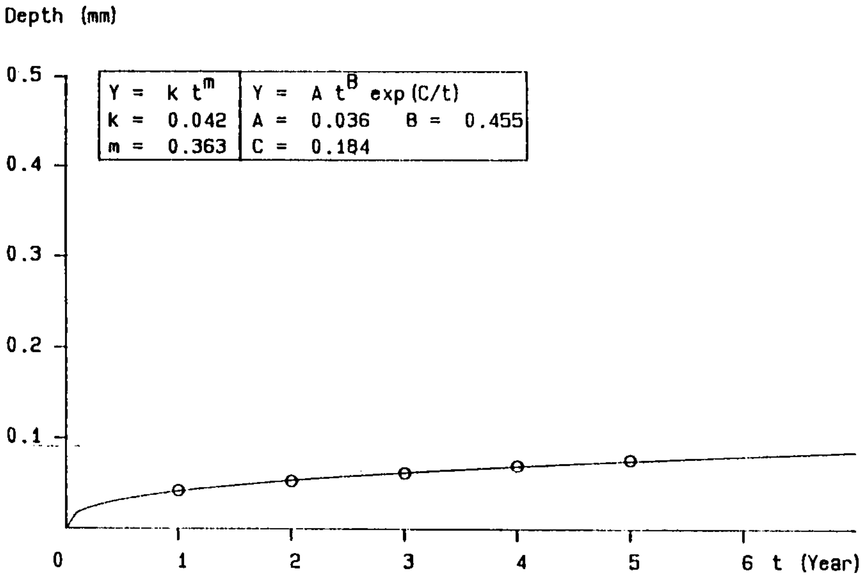

Fig. A1-E2 Long-term corrosion of bare steel exposed to rain
Sendai

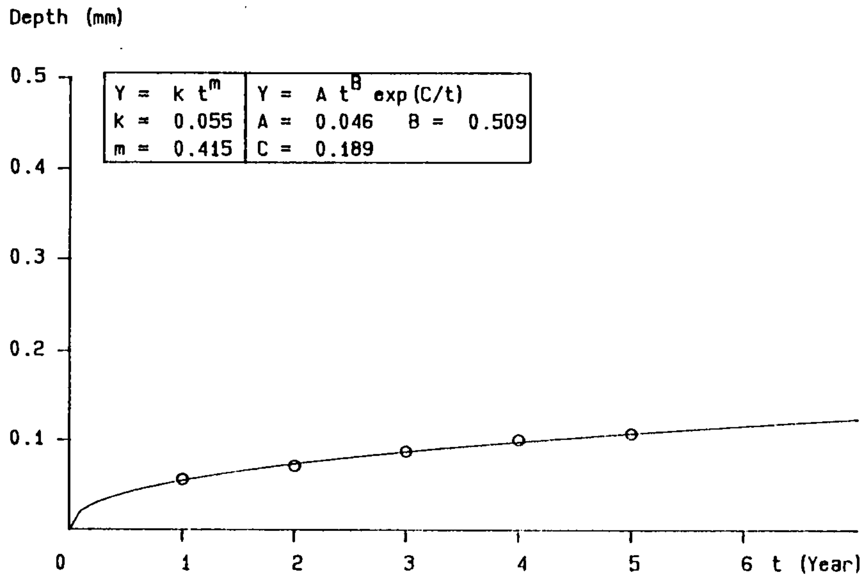

Fig. A1-E3 Long-term corrosion of bare steel exposed to rain
Niigata

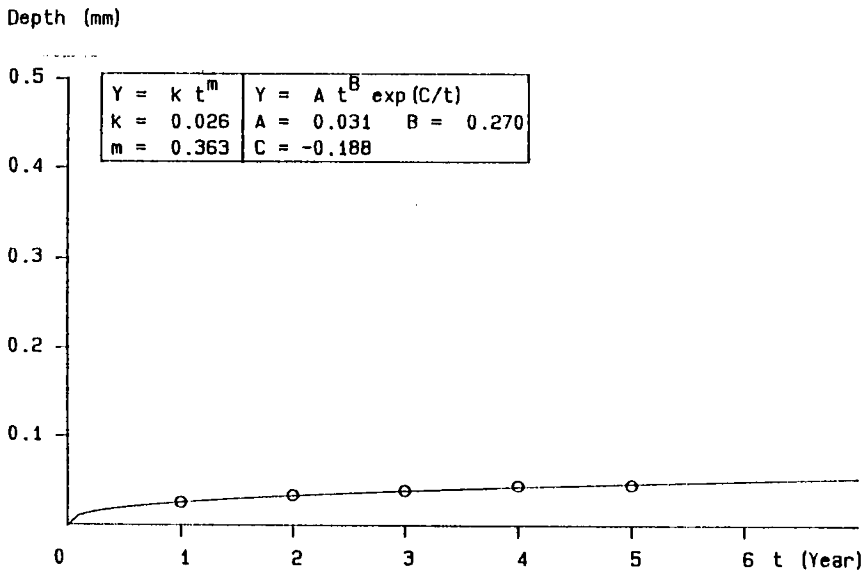

Fig. A1-E4 Long-term corrosion of bare steel exposed to rain
Nagano

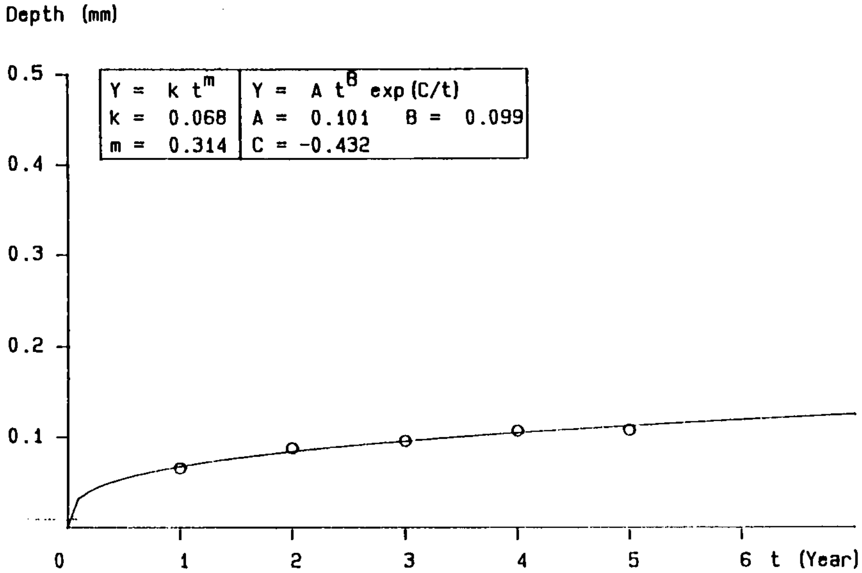

Fig. A1-E5 Long-term corrosion of bare steel exposed to rain
Nagoya

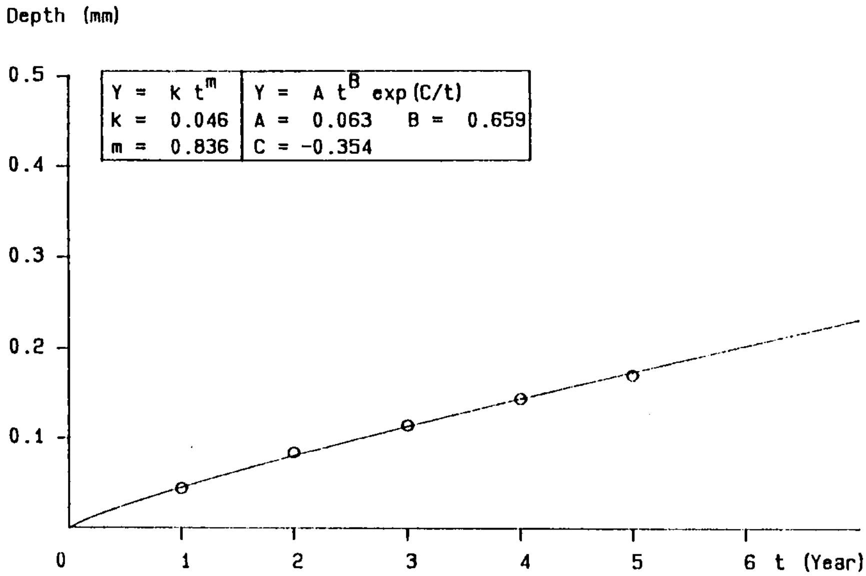

Fig. A1-E6 Long-term corrosion of bare steel exposed to rain
Shimizu

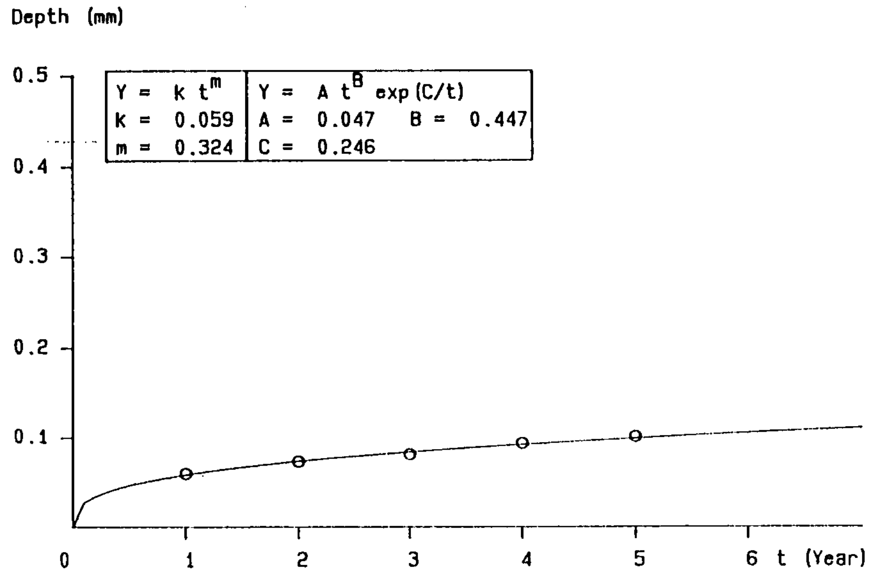

Fig. A1-E7 Long-term corrosion of bare steel exposed to rain
Tokyo

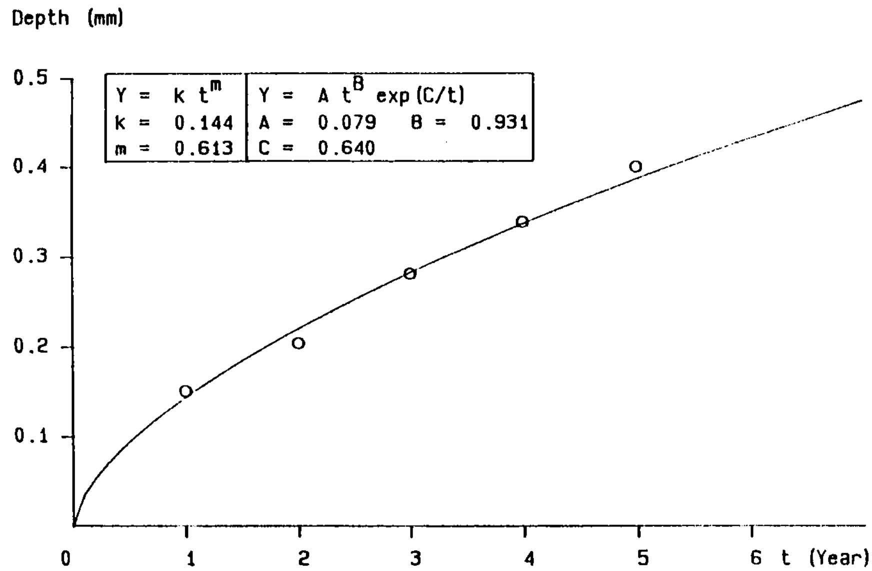

Fig. A1-E8 Long-term corrosion of bare steel exposed to rain
Kawasaki

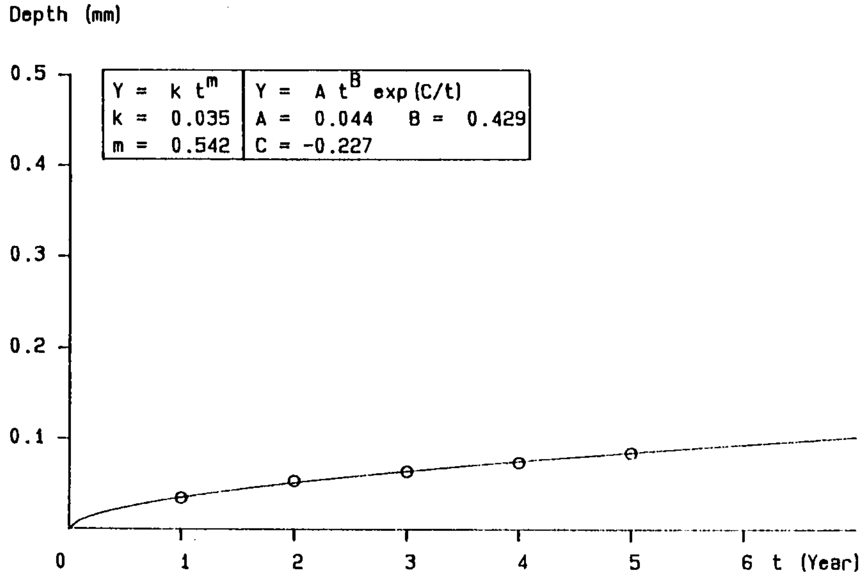

Fig. A1-E9 Long-term corrosion of bare steel exposed to rain
Matsue

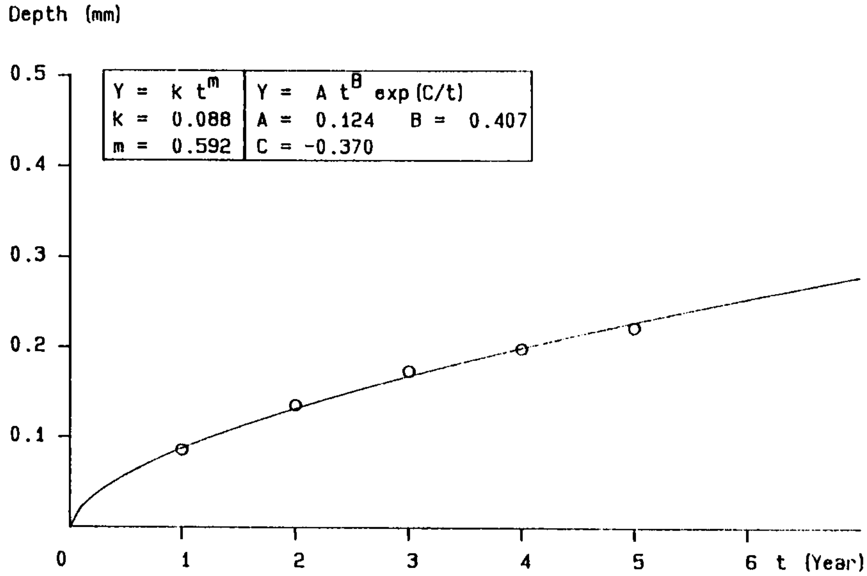

Fig. A1-E10 Long-term corrosion of bare steel exposed to rain
Amagasaki

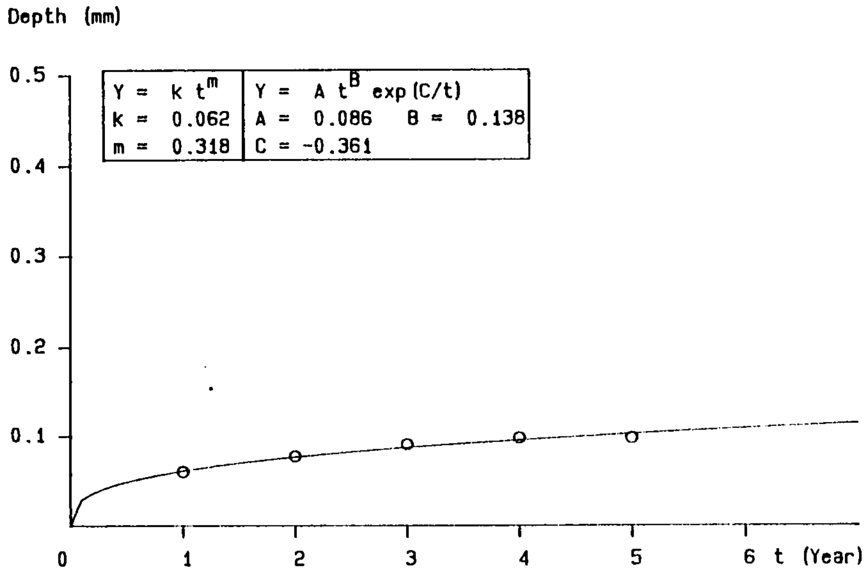

Fig. A1-E11 Long-term corrosion of bare steel exposed to rain
Wakayama

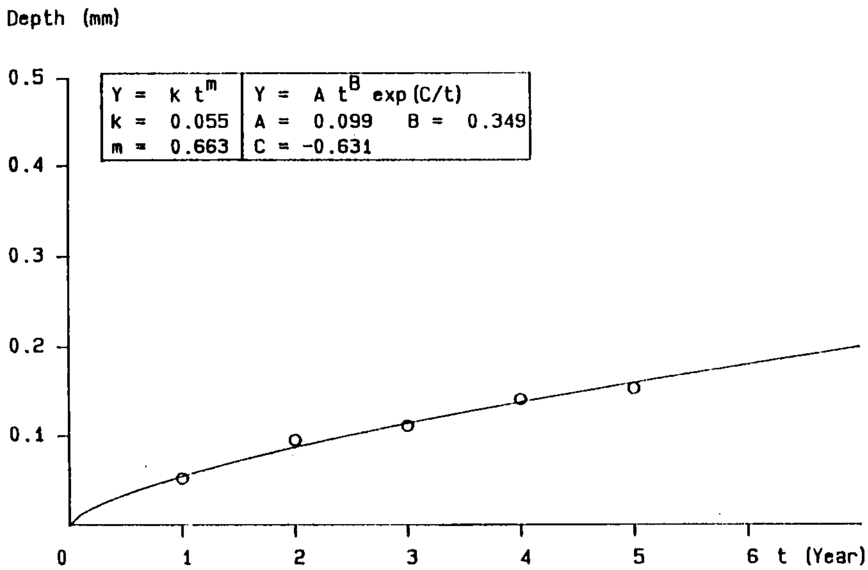

Fig. A1-E12 Long-term corrosion of bare steel exposed to rain
Shionomisaki

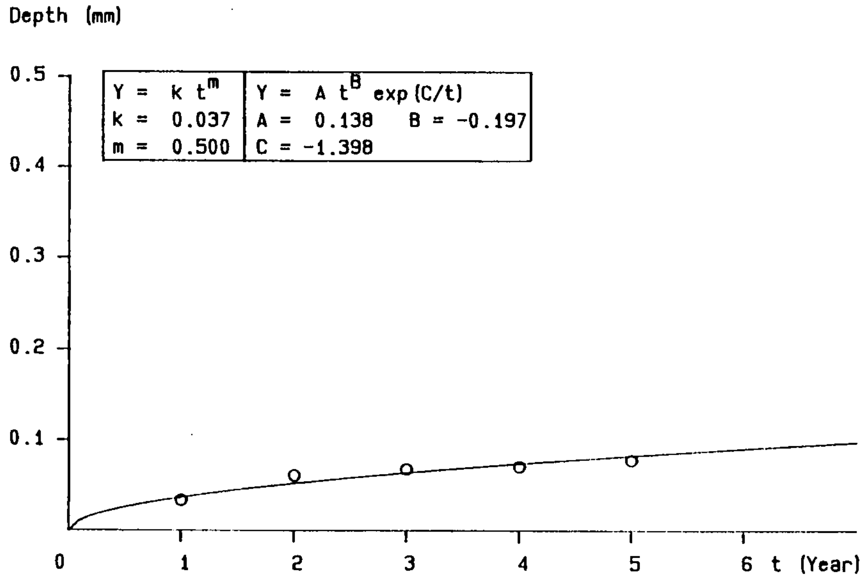

Fig. A1-E13 Long-term corrosion of bare steel exposed to rain
Miyasaki

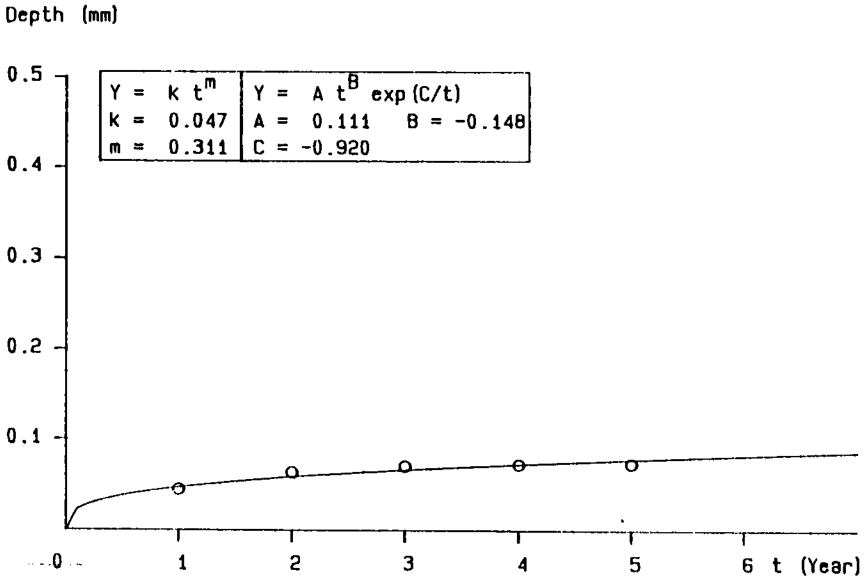

Fig. A1-E14 Long-term corrosion of bare steel exposed to rain
Matsuyama

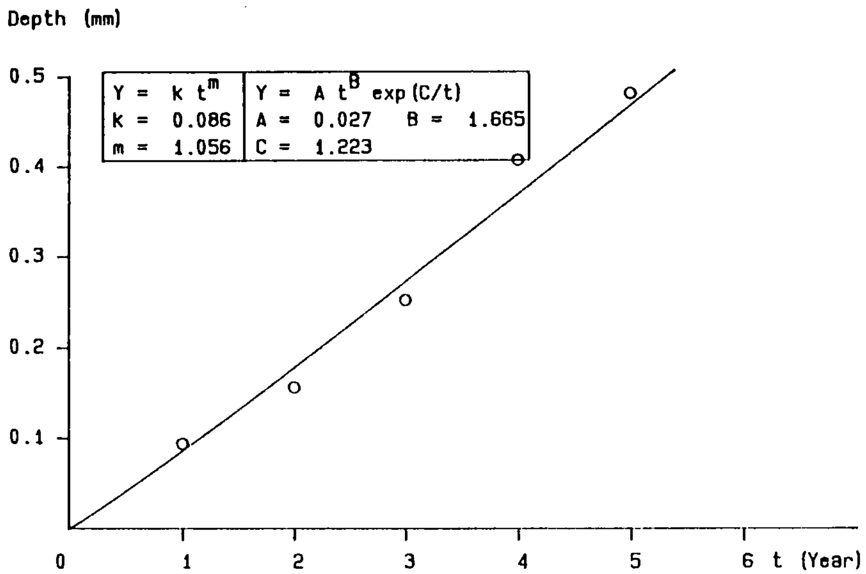

Fig. A1-E15 Long-term corrosion of bare steel exposed to rain
Ashizurimisaki

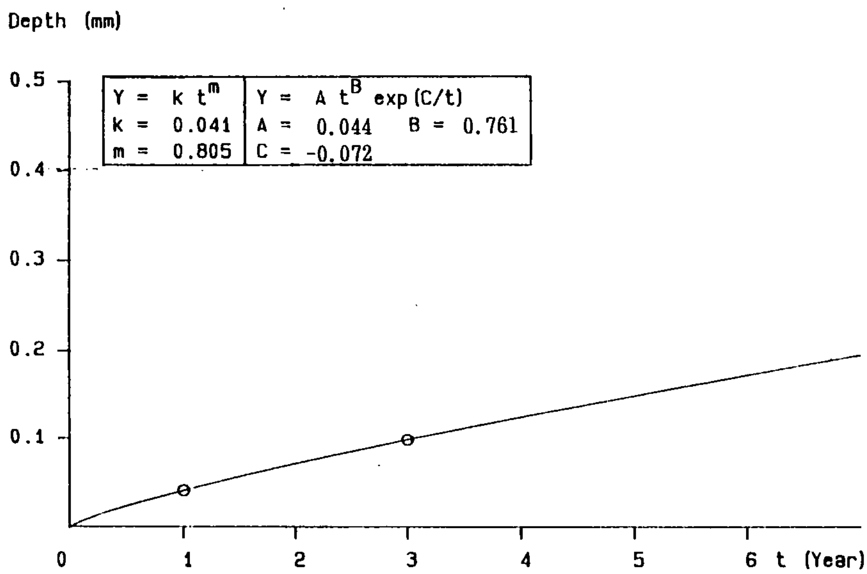

Fig. A1-U1 Long-term corrosion of bare steel underneath bridges
Ishikari

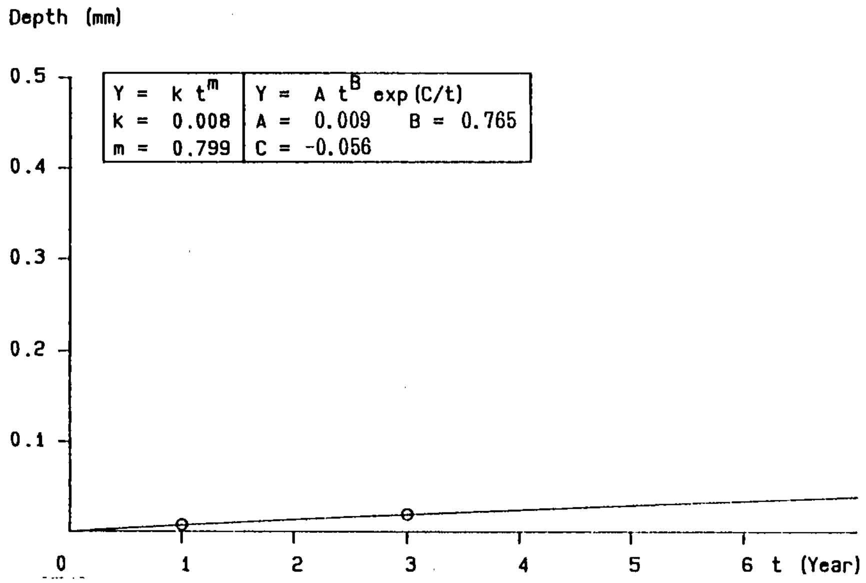

Fig. A1-U2 Long-term corrosion of bare steel underneath bridges
Sapporo

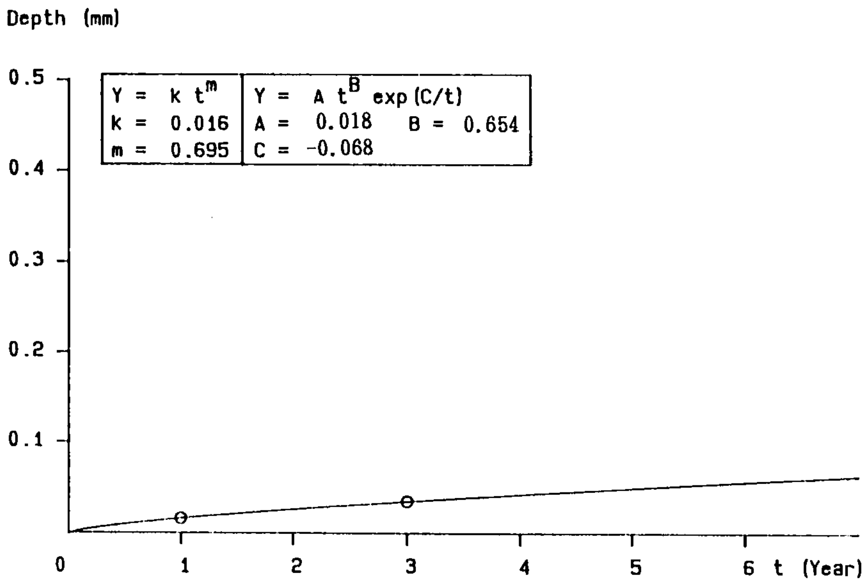

Fig. A1-U3 Long-term corrosion of bare steel underneath bridges
Chitose

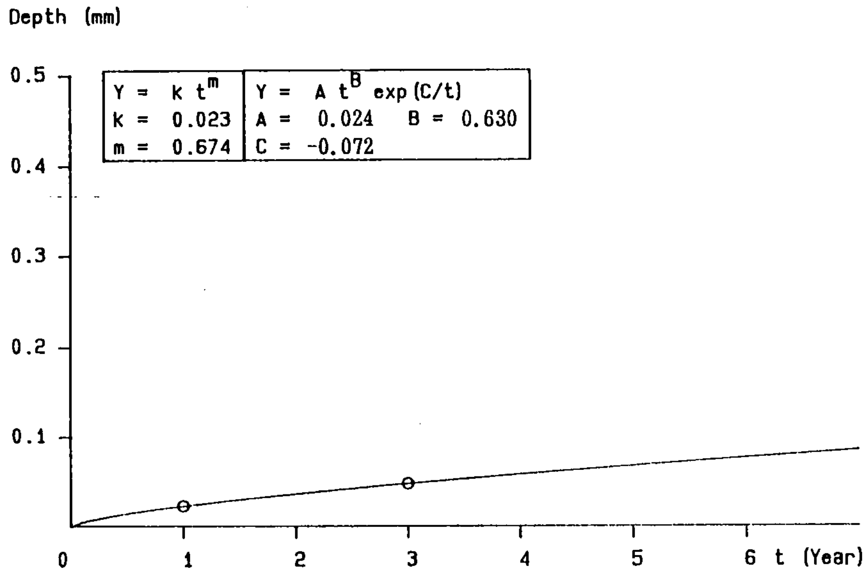

Fig. A1-U4 Long-term corrosion of bare steel underneath bridges
Muroran

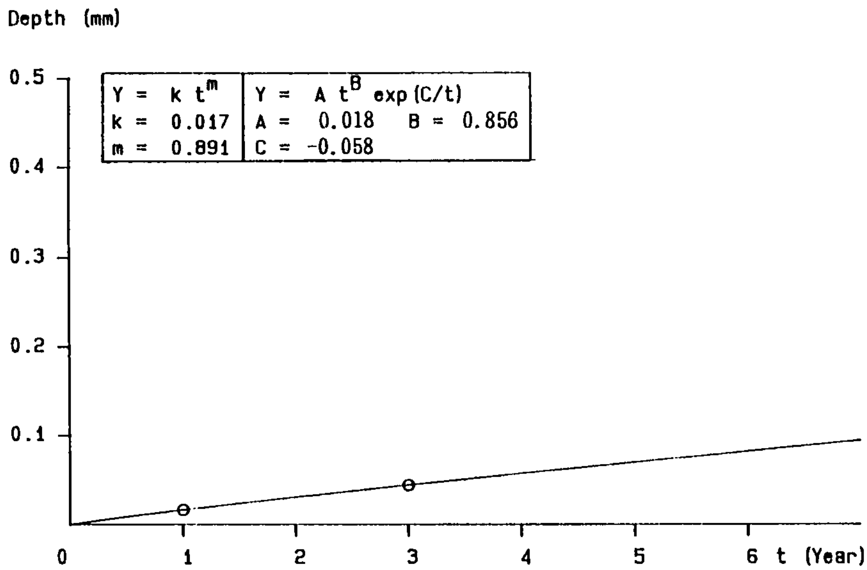

Fig. A1-U5 Long-term corrosion of bare steel underneath bridges
Matsushima

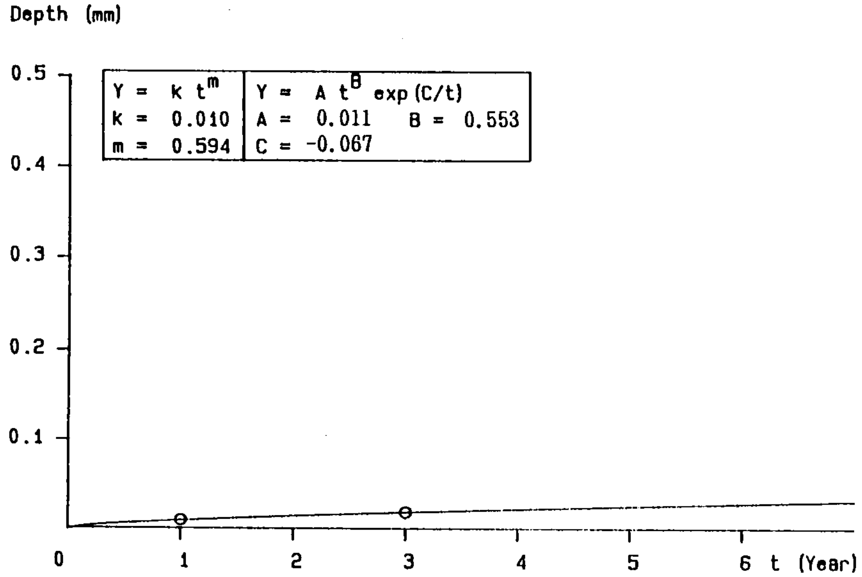

Fig. A1-U6 Long-term corrosion of bare steel underneath bridges
Higashine

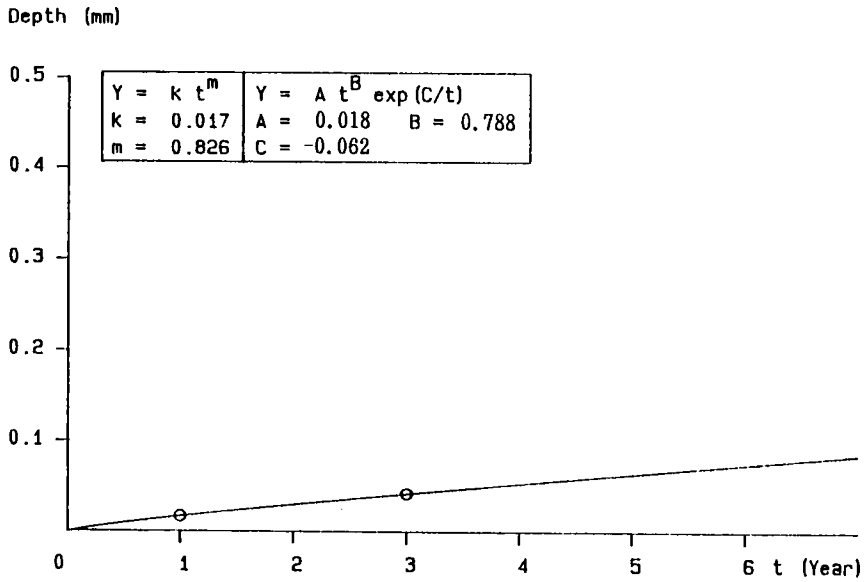

Fig. A1-U7 Long-term corrosion of bare steel underneath bridges
Sendai

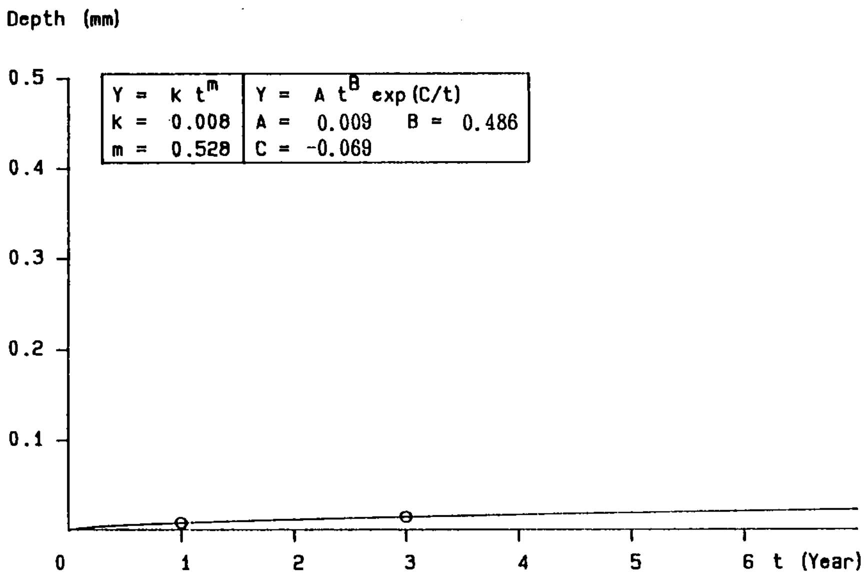

Fig. A1-U8 Long-term corrosion of bare steel underneath bridges
Shinji, Tone

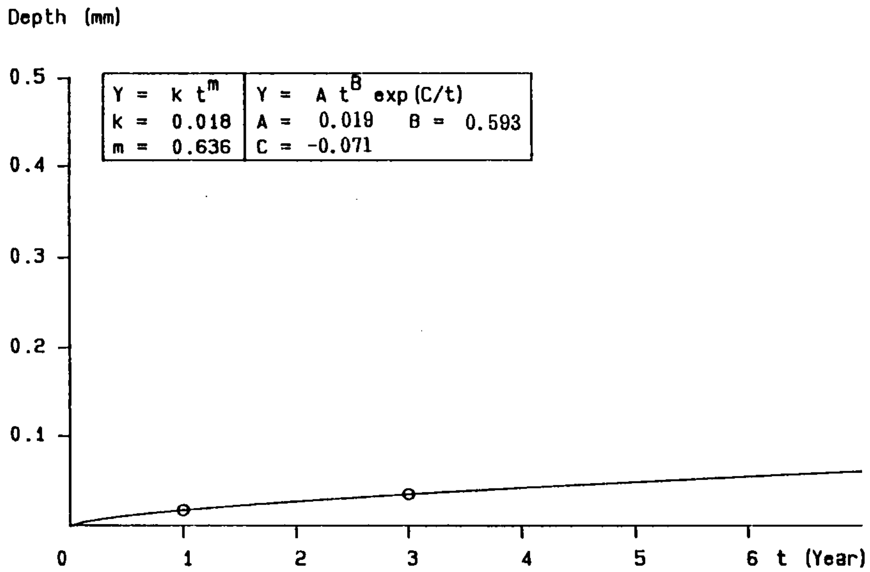

Fig. A1-U9 Long-term corrosion of bare steel underneath bridges
Omiya

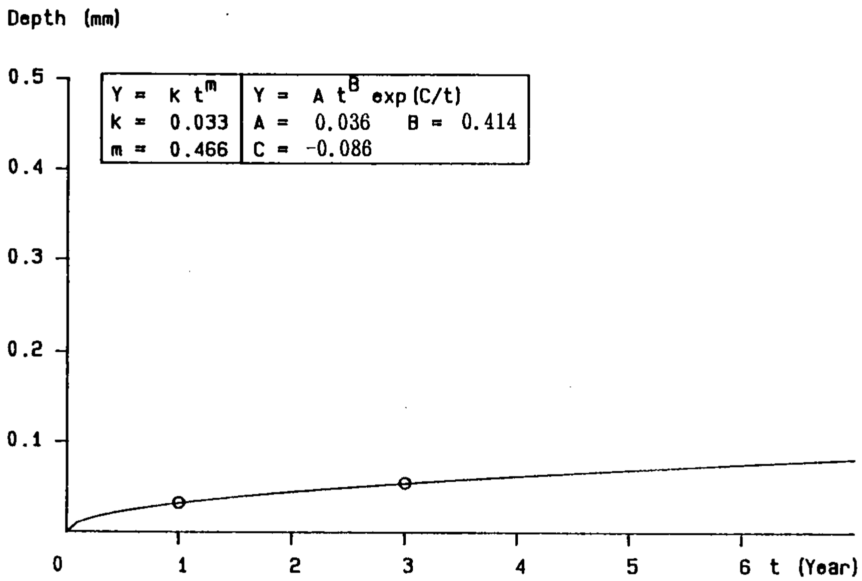

Fig. A1-U10 Long-term corrosion of bare steel underneath bridges
Funabashi

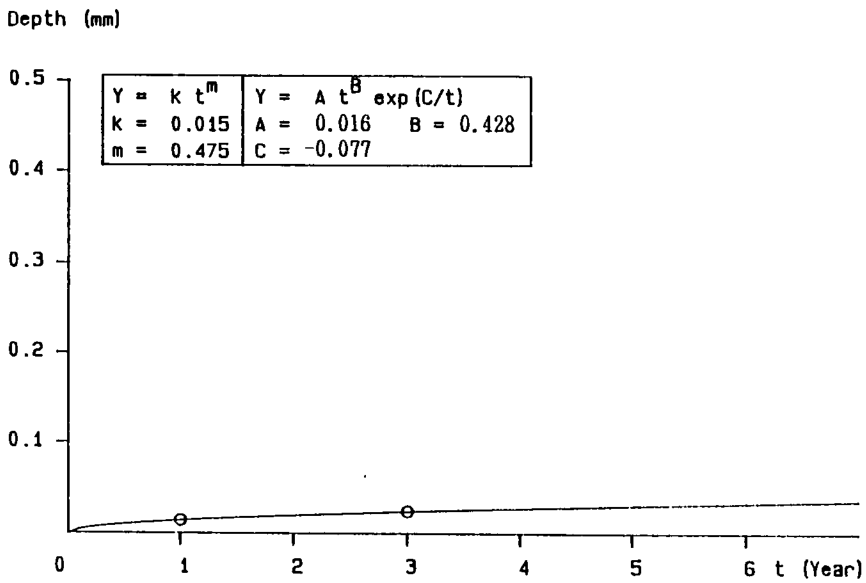

Fig. A1-U11 Long-term corrosion of bare steel underneath bridges
Yokohama

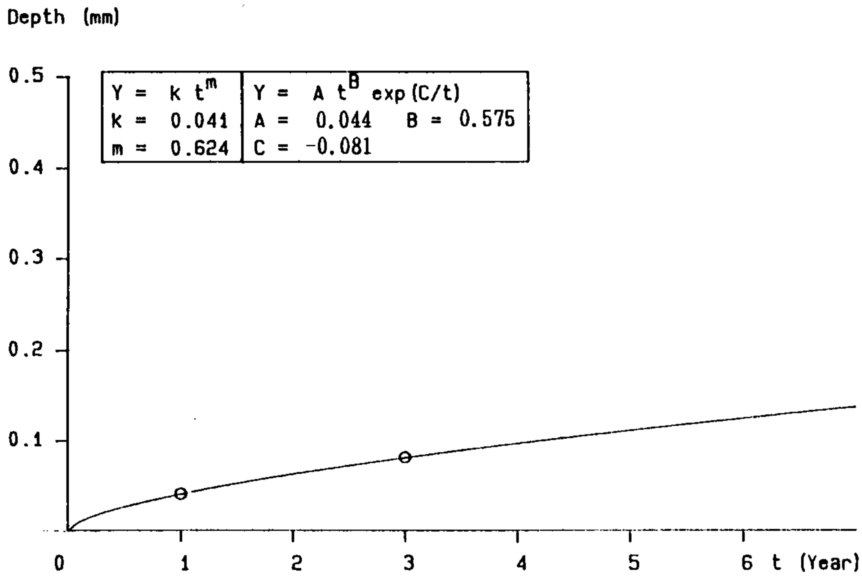

Fig. A1-U12 Long-term corrosion of bare steel underneath bridges
Nagaoka

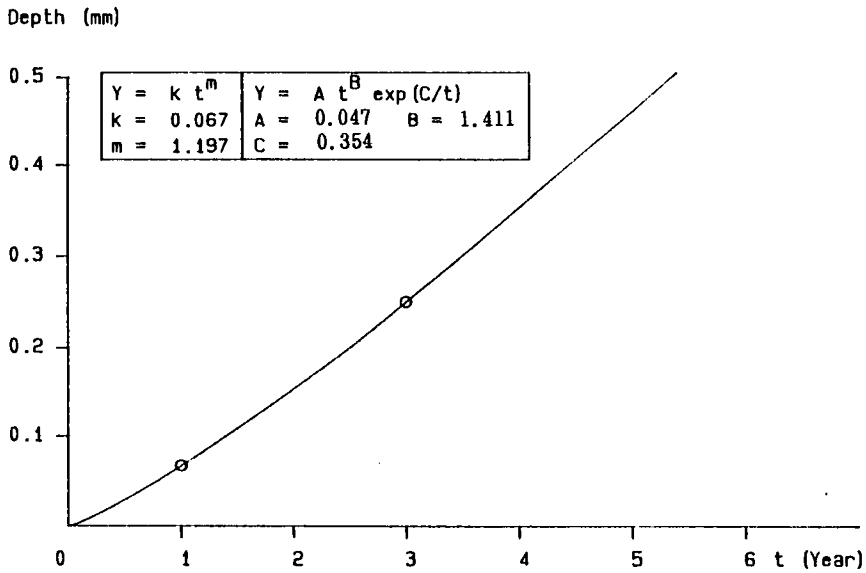

Fig. A1-U13 Long-term corrosion of bare steel underneath bridges
Kashiwazaki

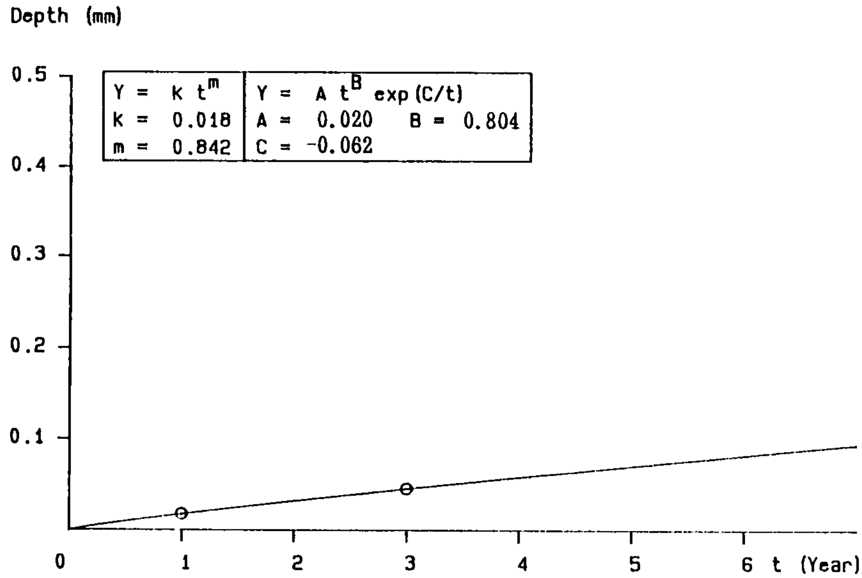

Fig. A1-U14 Long-term corrosion of bare steel underneath bridges
Takaoka

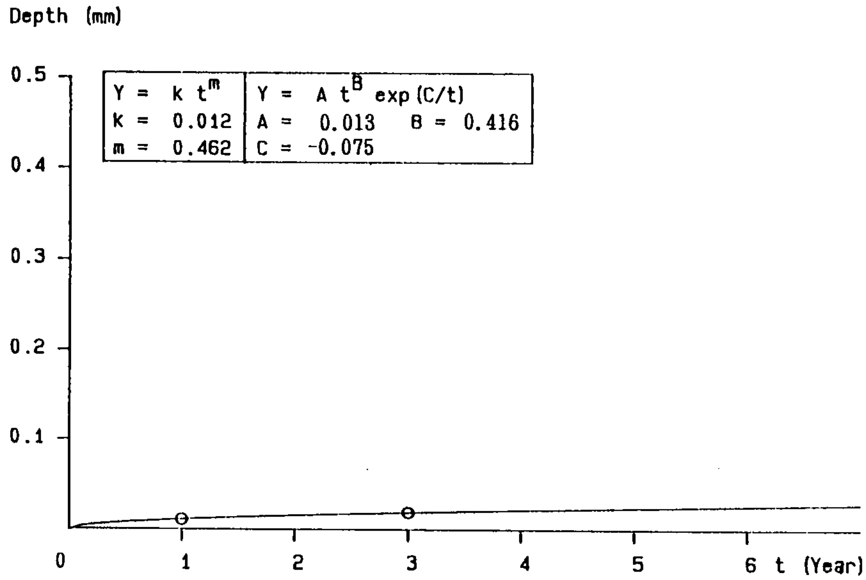

Fig. A1-U15 Long-term corrosion of bare steel underneath bridges
Tsugawa

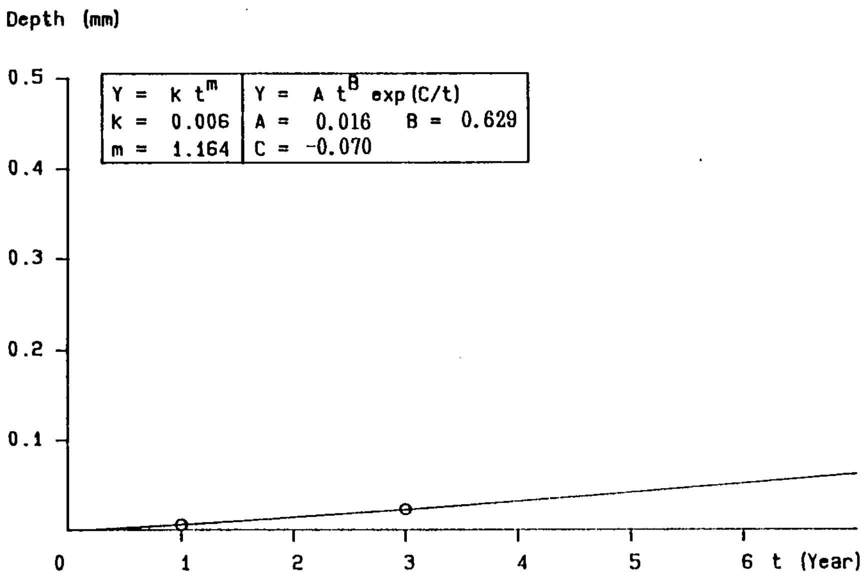

Fig. A1-U16 Long-term corrosion of bare steel underneath bridges
Furukawa

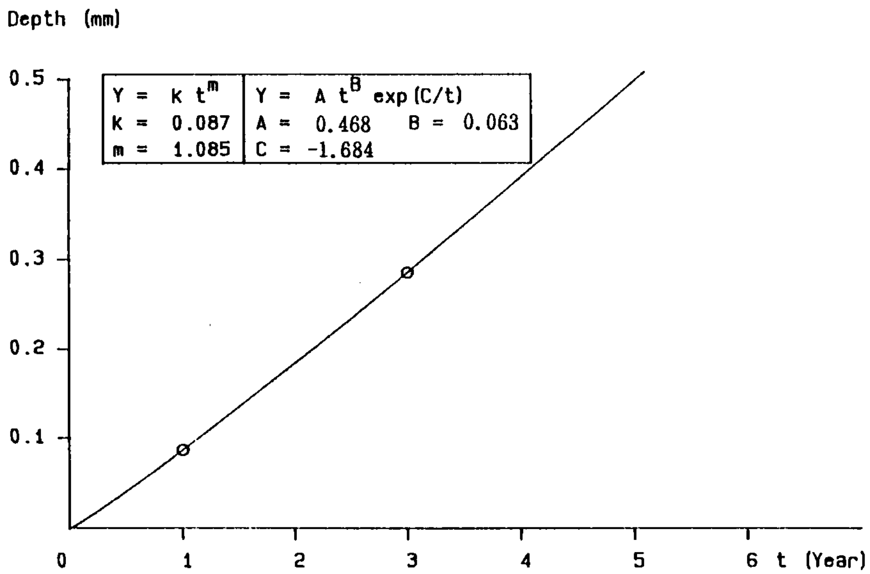

Fig. A1-U17 Long-term corrosion of bare steel underneath bridges
Ohama

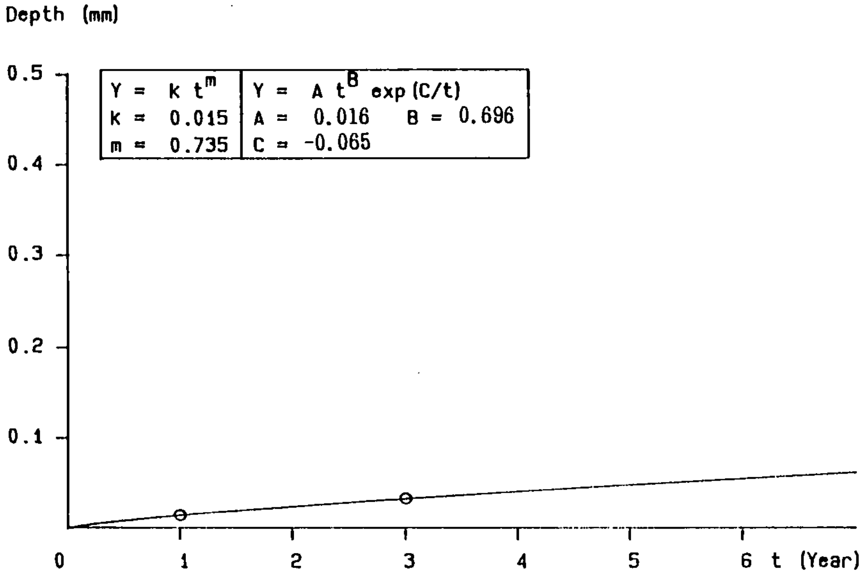

Fig. A1-U18 Long-term corrosion of bare steel underneath bridges
Nagoya

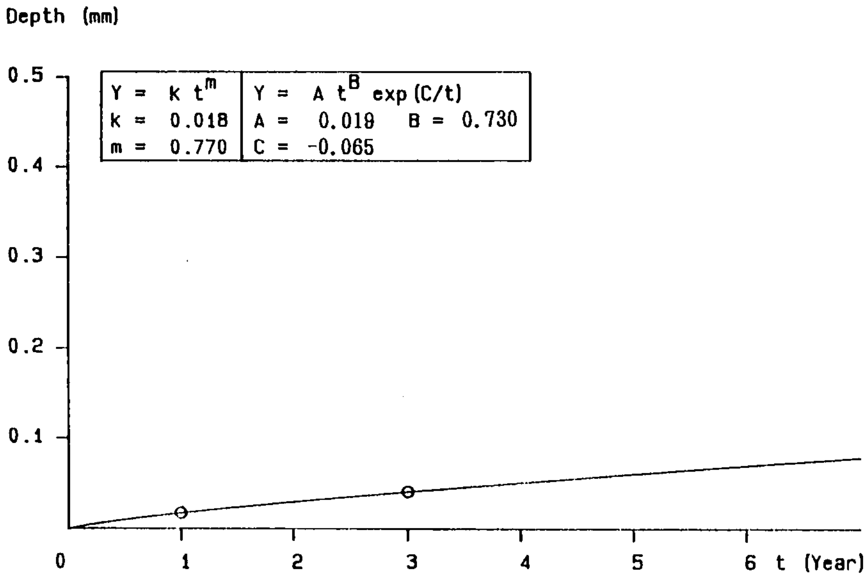

Fig. A1-U19 Long-term corrosion of bare steel underneath bridges
Yokkaichi

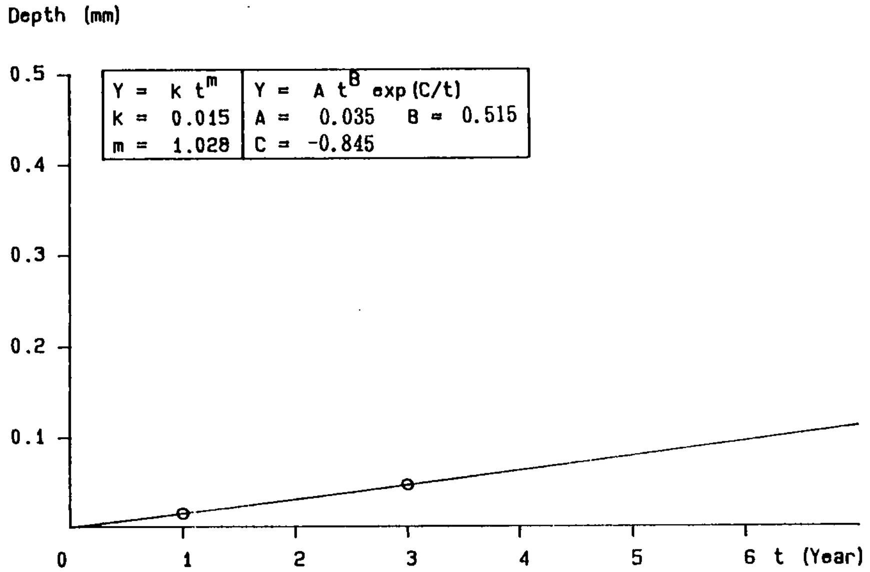

Fig. A1-U20 Long-term corrosion of bare steel underneath bridges
Arita by-pass

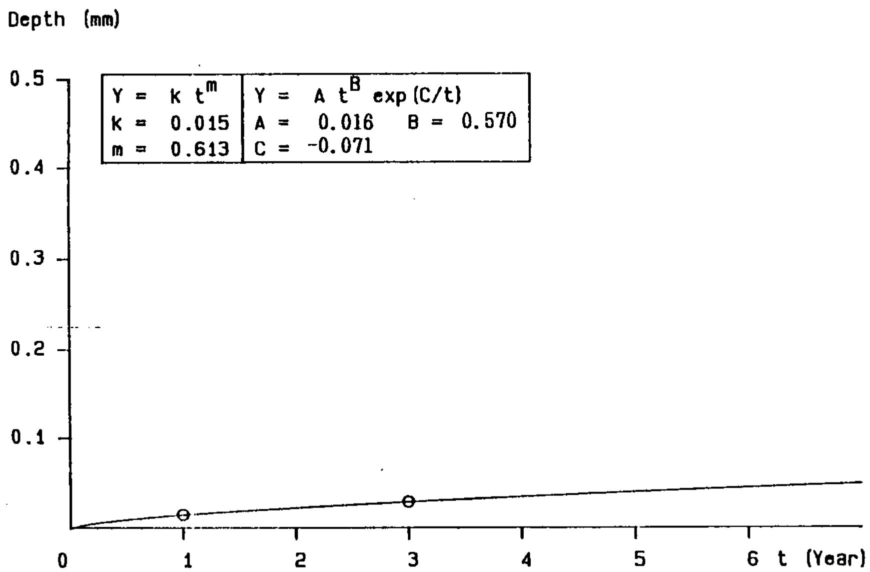

Fig. A1-U21 Long-term corrosion of bare steel underneath bridges
Otsu

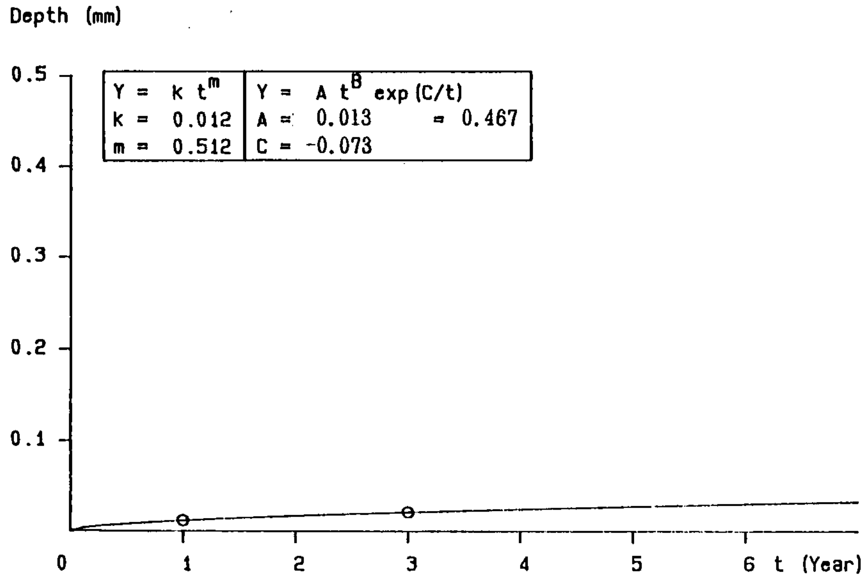

Fig. A1-U22 Long-term corrosion of bare steel underneath bridges
Kyoto

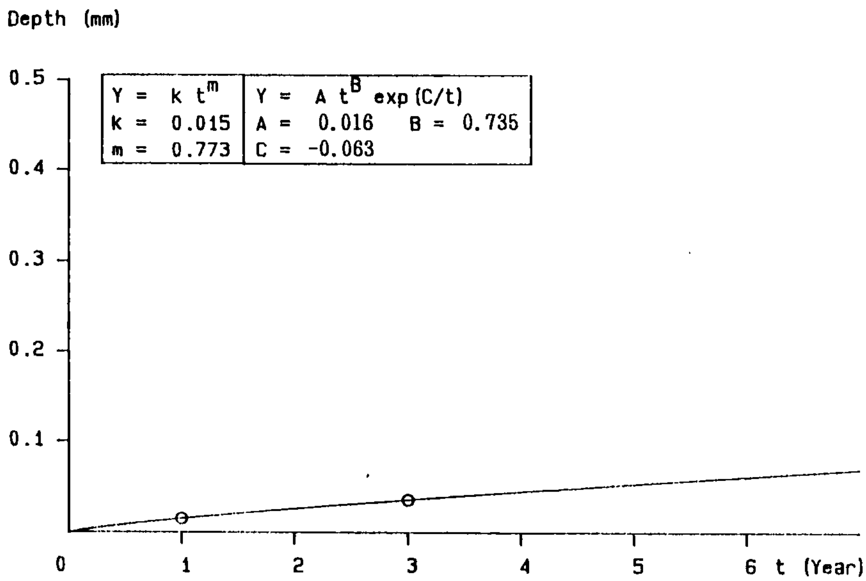

Fig. A1-U23 Long-term corrosion of bare steel underneath bridges
Osaka

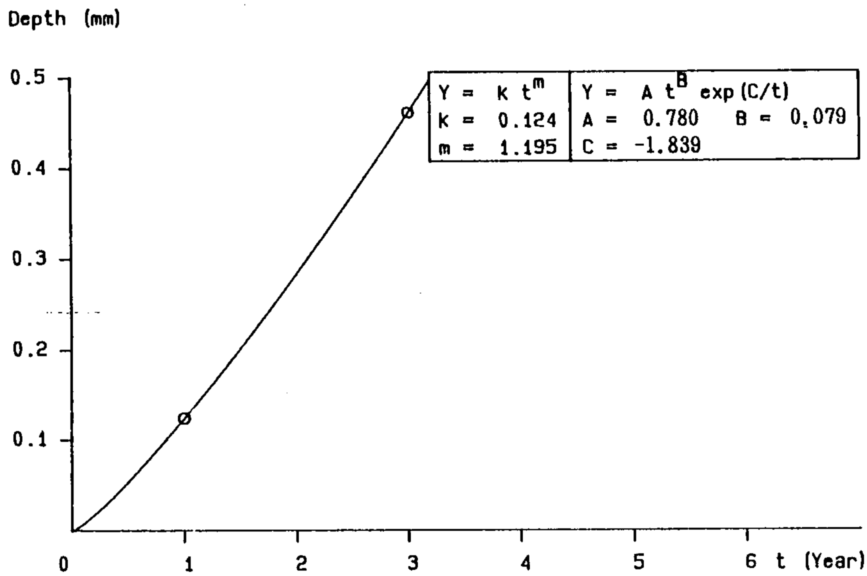

Fig. A1-U24 Long-term corrosion of bare steel underneath bridges
Hoki, Kedaka

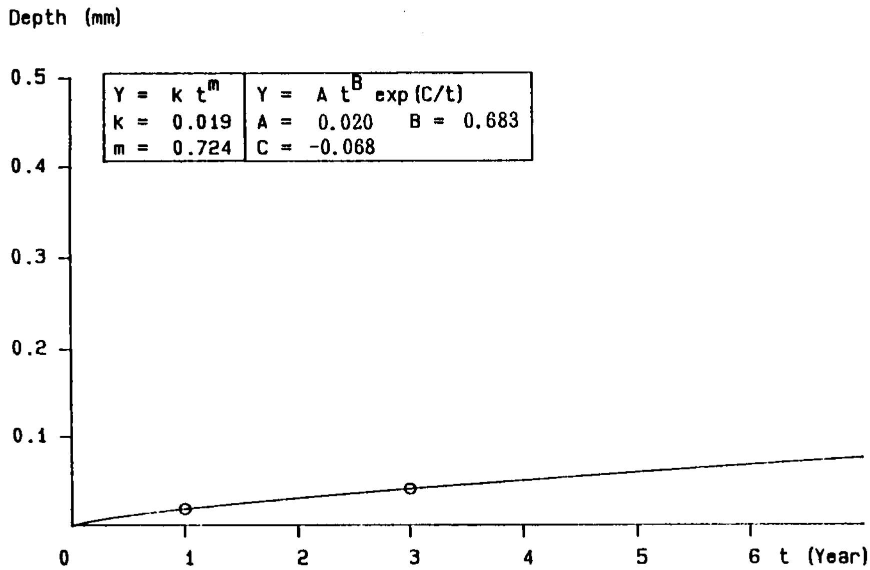

Fig. A1-U25 Long-term corrosion of bare steel underneath bridges
Gotsu

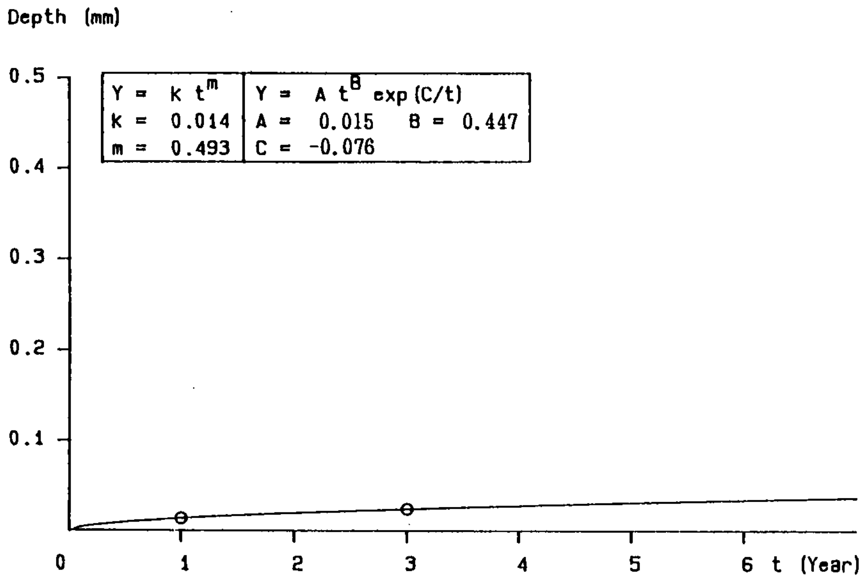

Fig. A1-U26 Long-term corrosion of bare steel underneath bridges
Miyoshi

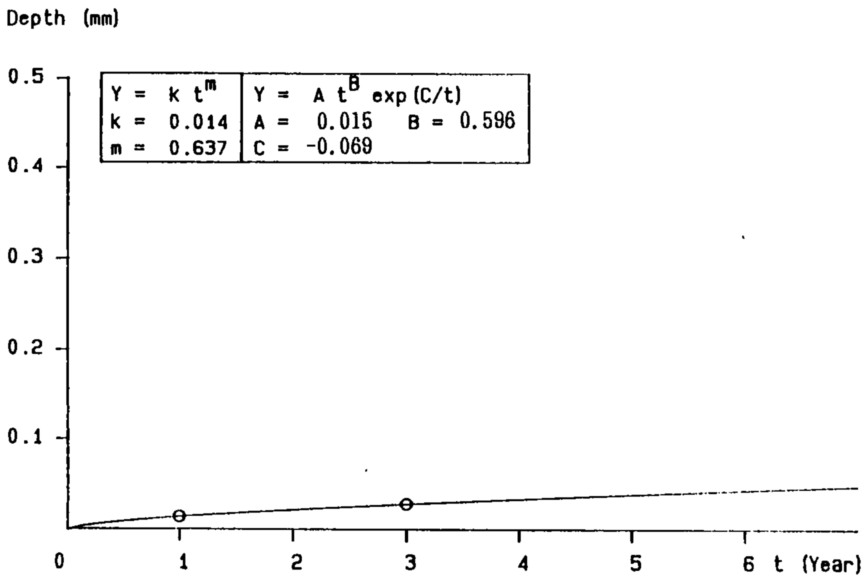

Fig. A1-U27 Long-term corrosion of bare steel underneath bridges
Okayama

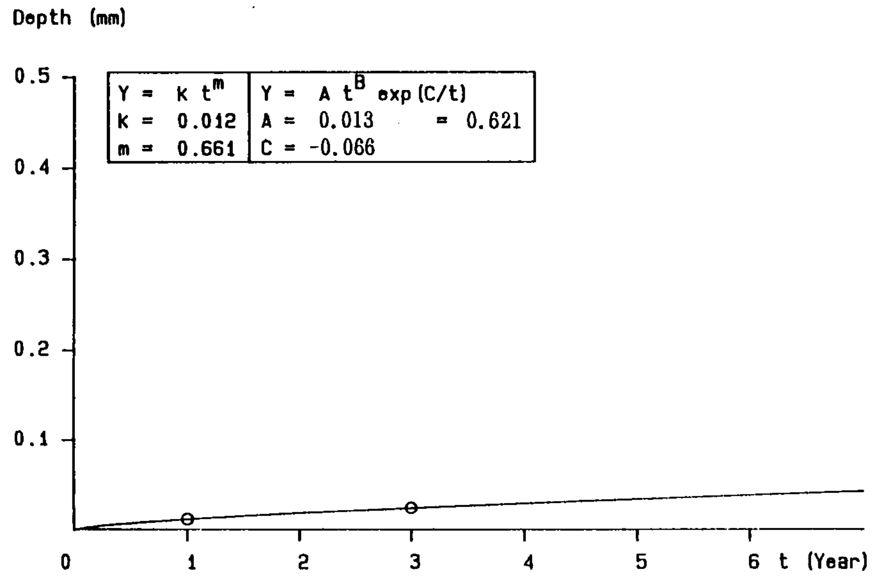

Fig. A1-U28 Long-term corrosion of bare steel underneath bridges
Kurashiki

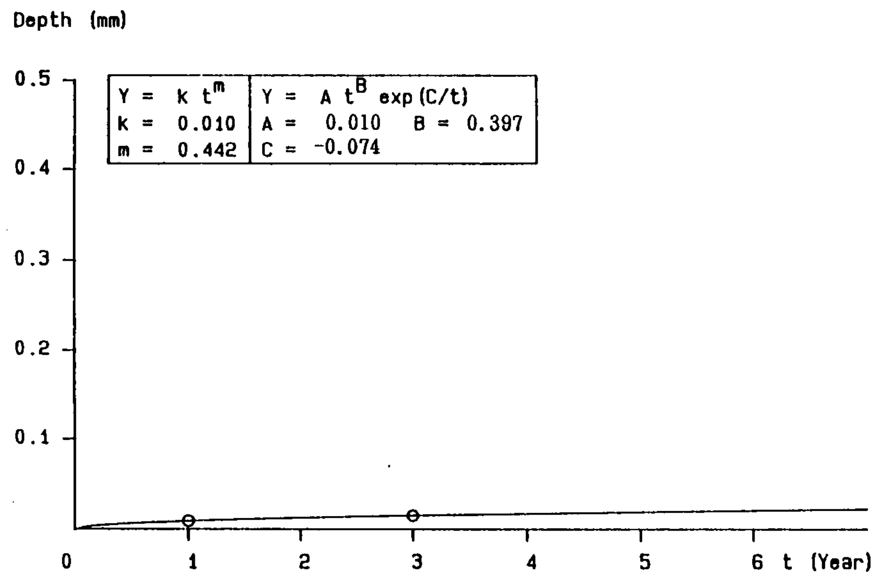

Fig. A1-U29 Long-term corrosion of bare steel underneath bridges
Kagawa-Tokushima

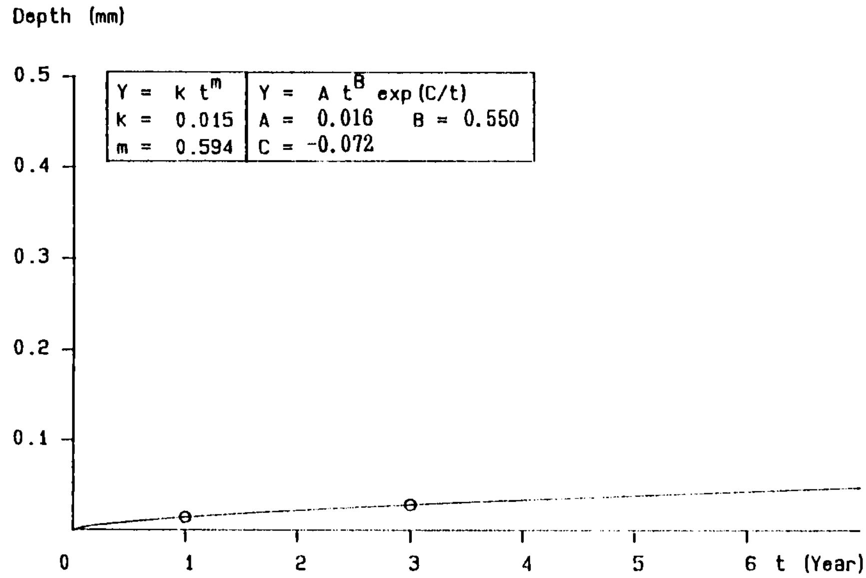

Fig. A1-U30 Long-term corrosion of bare steel underneath bridges
Matsuyama

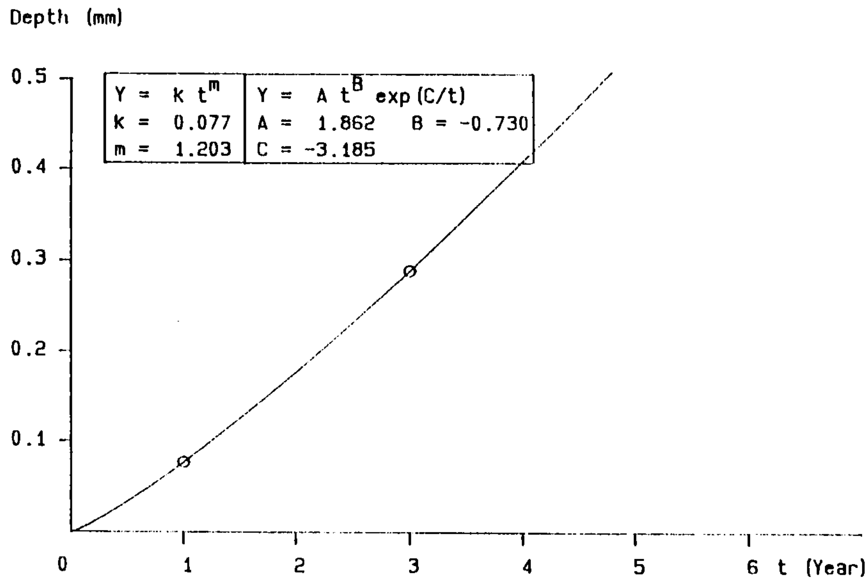

Fig. A1-U31 Long-term corrosion of bare steel underneath bridges
Yasuda

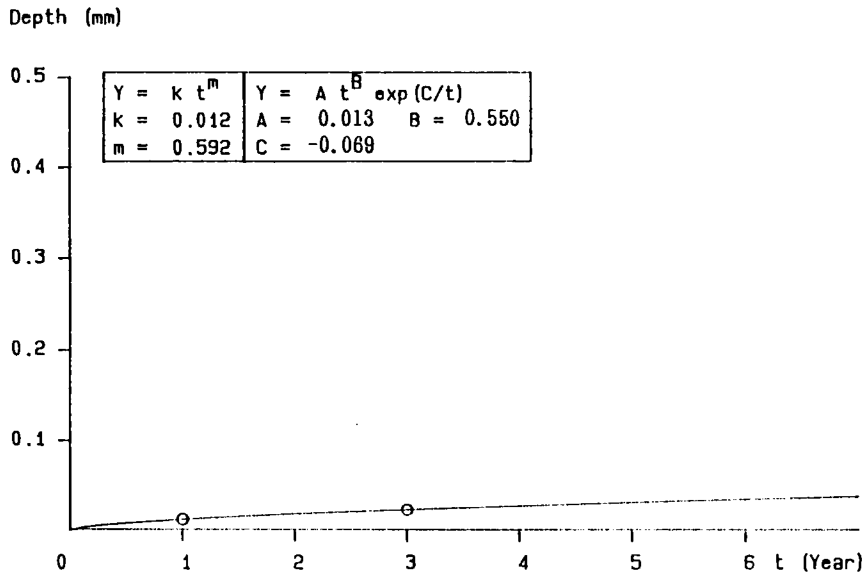

Fig. A1-U32 Long-term corrosion of bare steel underneath bridges
Ozu

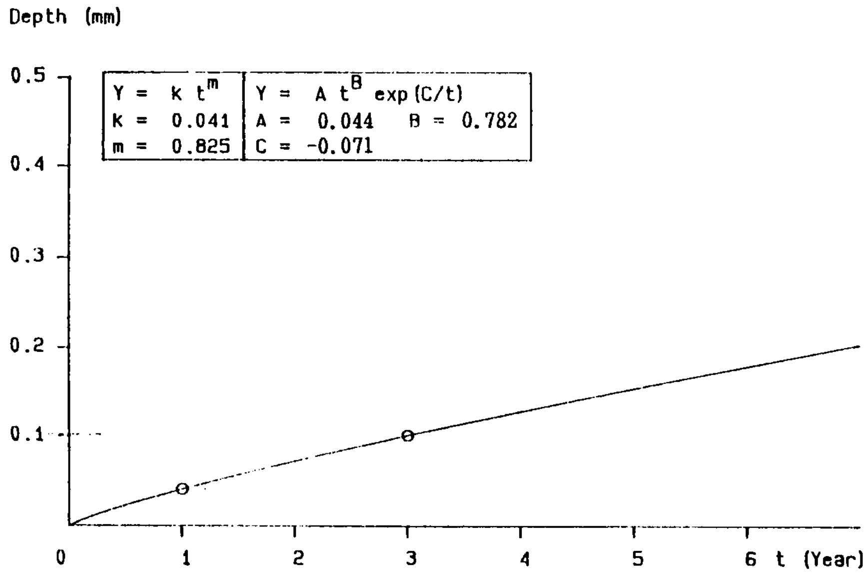

Fig. A1-U33 Long-term corrosion of bare steel underneath bridges
Miyazaki

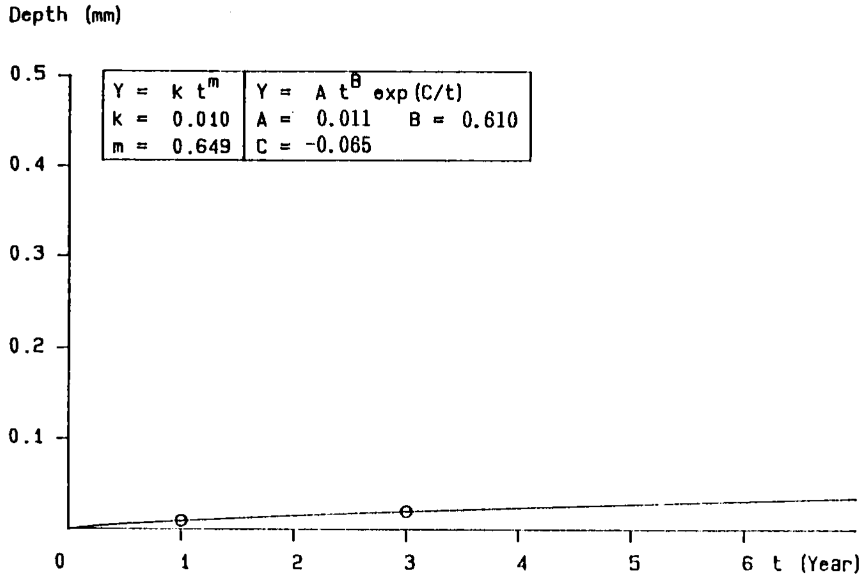

Fig. A1-U34 Long-term corrosion of bare steel underneath bridges
Kashiwabara, Kuju

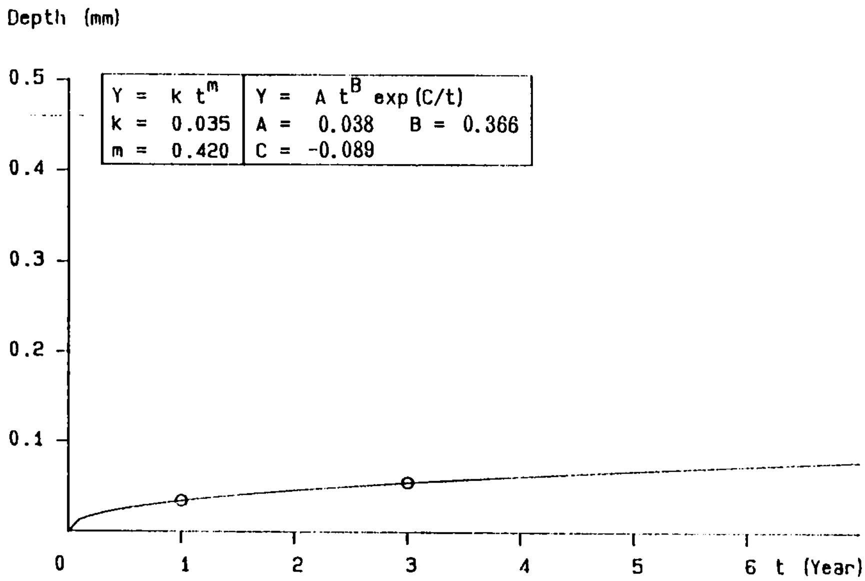

Fig. A1-U35 Long-term corrosion of bare steel underneath bridges
Fukuoka

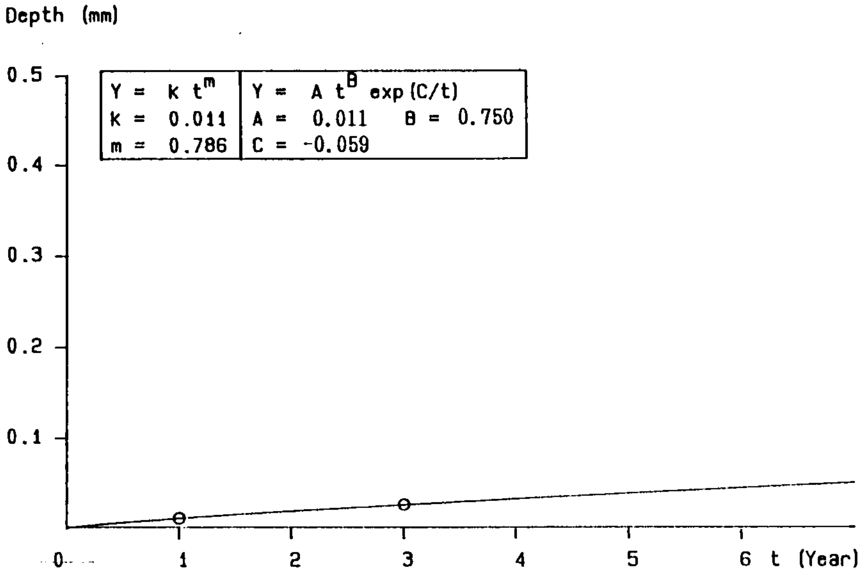

Fig. A1-U36 Long-term corrosion of bare steel underneath bridges
Kitakyushu

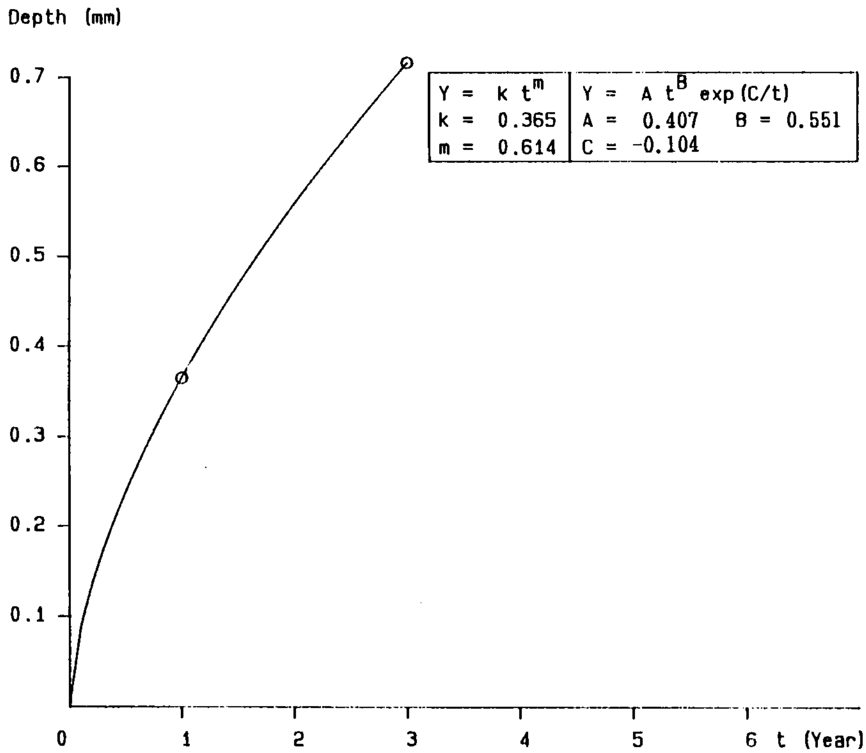

Fig. A1-U37 Long-term corrosion of bare steel underneath bridges
Ogimi, Shioya-wan

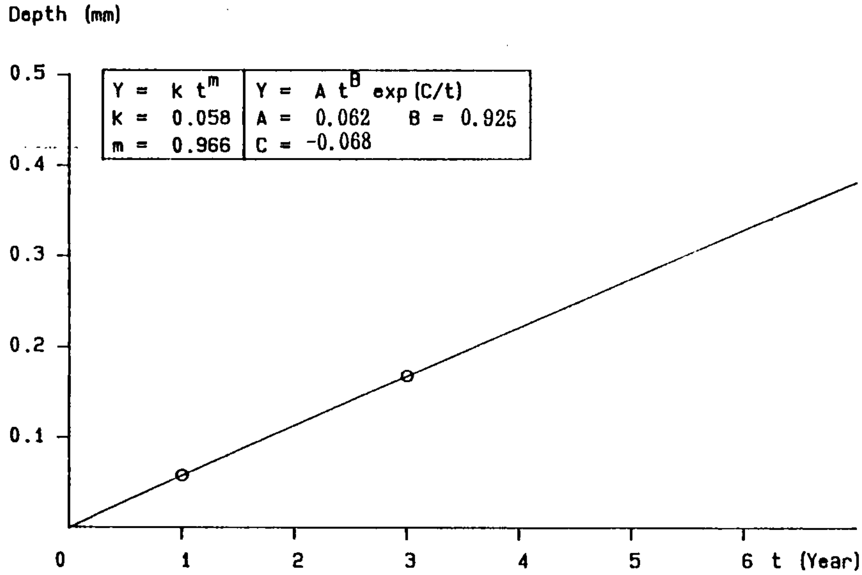

Fig. A1-U38 Long-term corrosion of bare steel underneath bridges
Nago

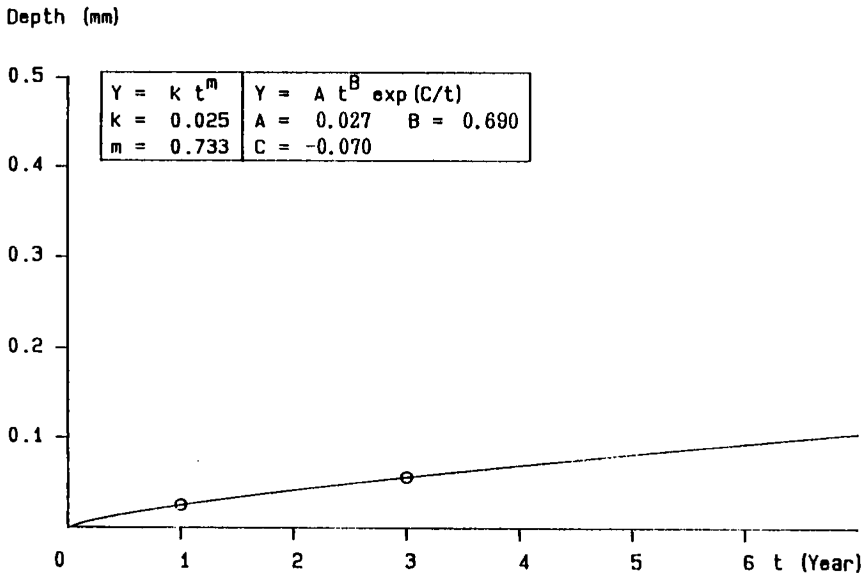

Fig. A1-U39 Long-term corrosion of bare steel underneath bridges
Okinawa

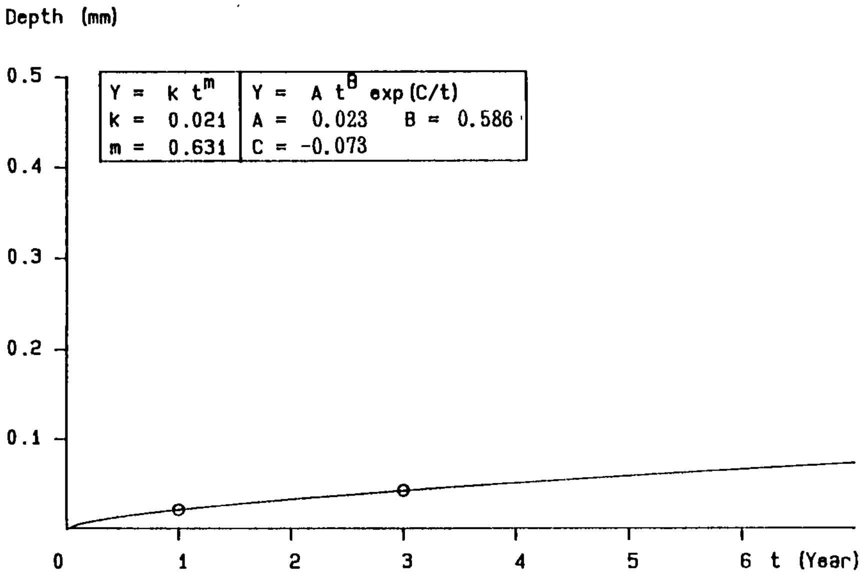

Fig. A1-U40 Long-term corrosion of bare steel underneath bridges
Naha

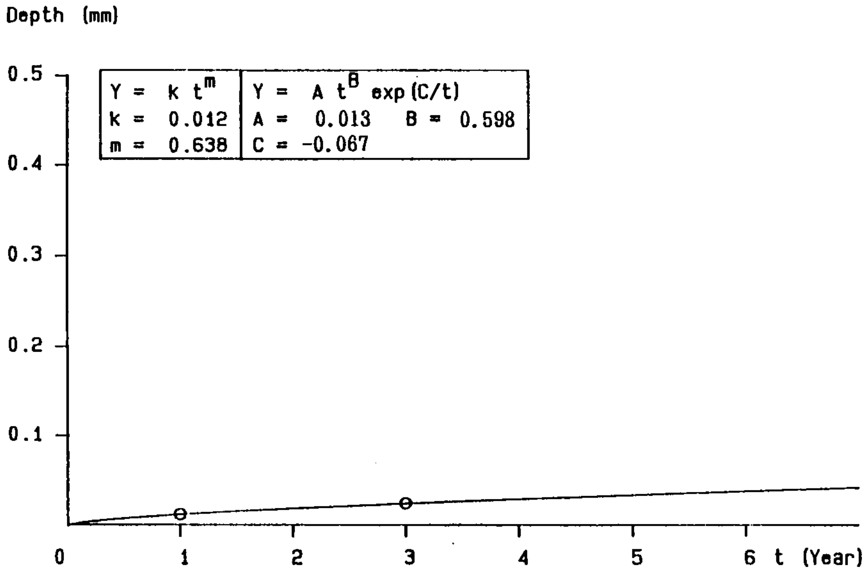

Fig. A1-U41 Long-term corrosion of bare steel underneath bridges
Public Work Research Institute

RN of paint

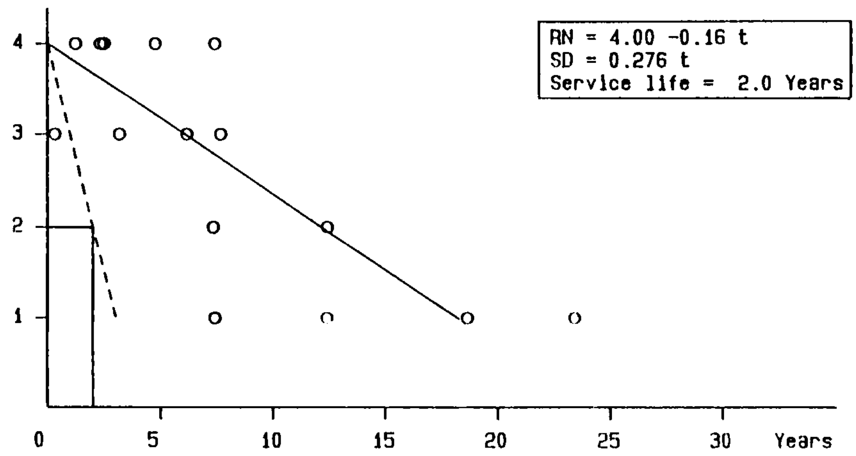

Fig. A2-1 Relation between RN of paint film deterioration and exposure time
P1 End part of span of main girder (External girder)
Shoe (City A, Rural envi.)
Paint type = Alkyd resins (N=16)

RN of paint

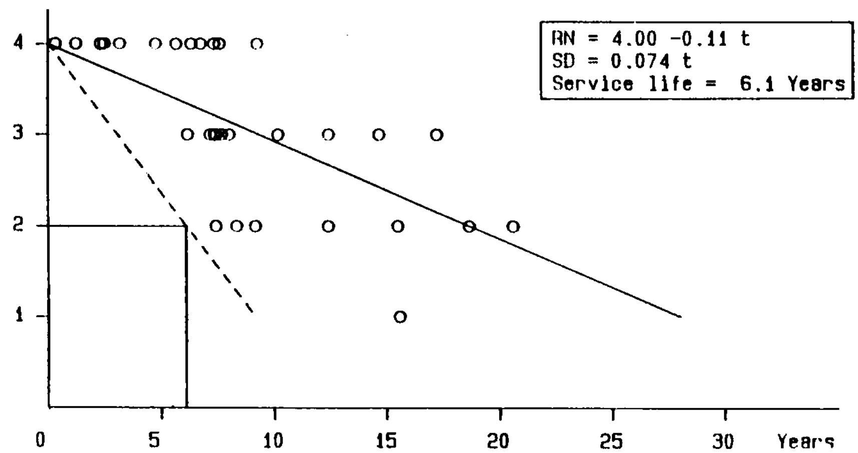

Fig. A2-2 Relation between RN of paint film deterioration and exposure time
P2 End part of span of main girder (External girder)
Lower surface of upper flange - Outer side (City A, Rural envi.)
Paint type = Alkyd resins (N=31)

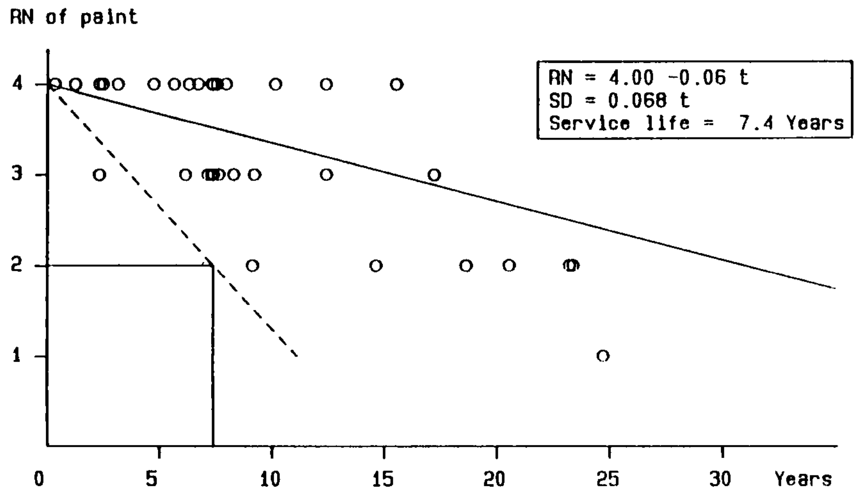

Fig. A2-3 Relation between RN of paint film deterioration and exposure time
P3 End part of span of main girder (External girder)
Lower surface of upper flange - Inner side (City A, Rural envi.)
Paint type = Alkyd resins (N=34)

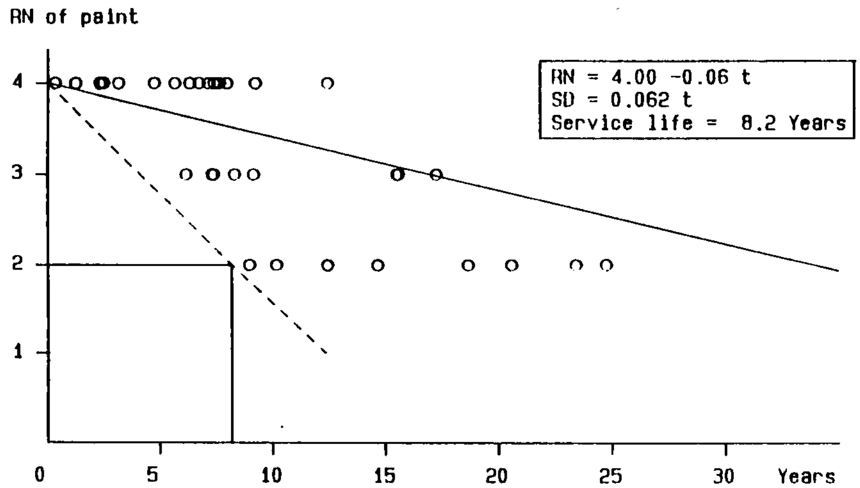

Fig. A2-4 Relation between RN of paint film deterioration and exposure time
P4 End part of span of main girder (External girder)
Web - Outer surface (City A, Rural envi.)
Paint type = Alkyd resins (N=36)

RN of paint

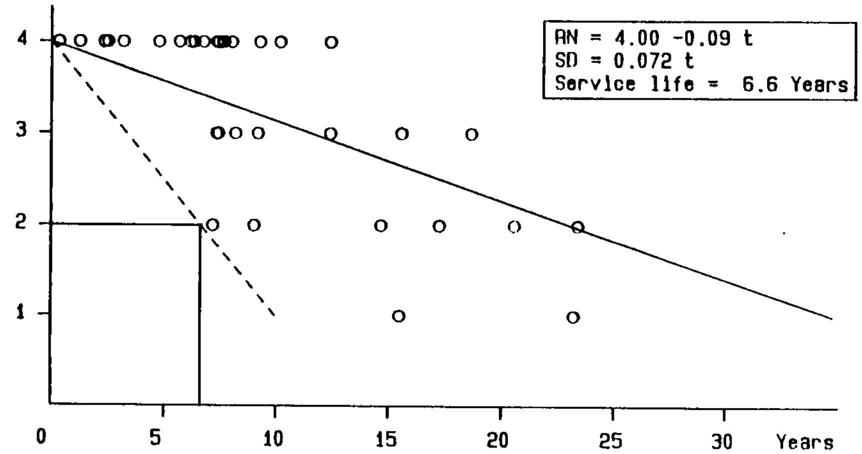

Fig. A2-5 Relation between RN of paint film deterioration and exposure time
P5 End part of span of main girder (External girder)
Web - Inner surface (City A. Rural envi.)
Paint type = Alkyd resins (N=35)

RN of paint

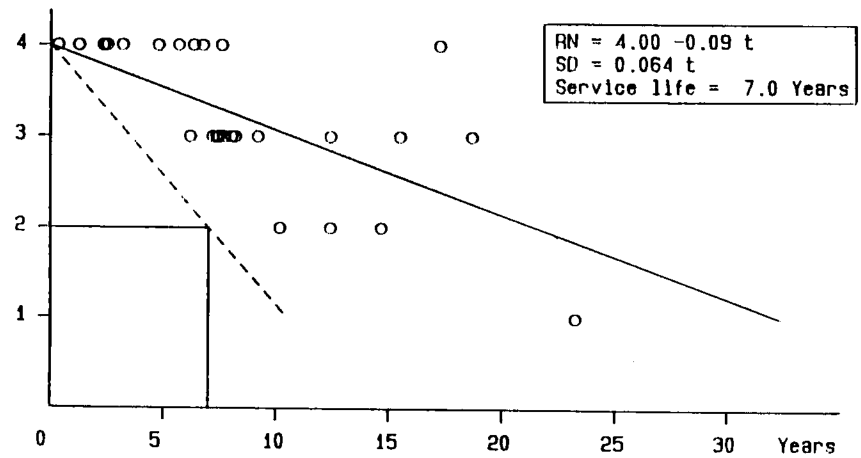

Fig. A2-6 Relation between RN of paint film deterioration and exposure time
P6 End part of span of main girder (External girder)
Upper surface of lower flange - Outer side (City A. Rural envi.)
Paint type = Alkyd resins (N=28)

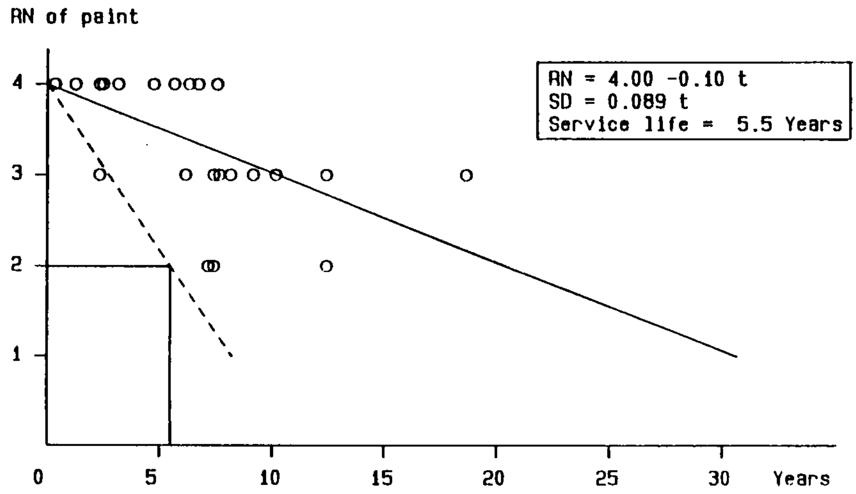

Fig. A2-7 Relation between RN of paint film deterioration and exposure time
P7 End part of span of main girder (External girder)
Upper surface of lower flange - Inner side (City A, Rural envi.)
Paint type = Alkyd resins (N=22)

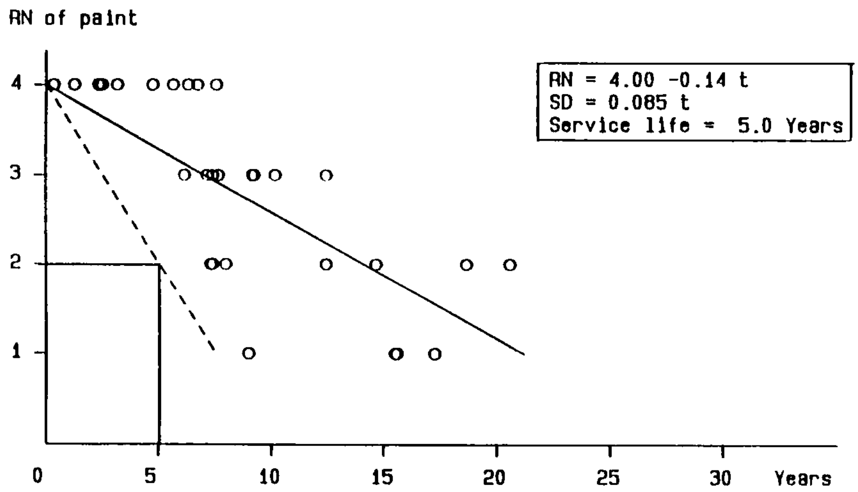

Fig. A2-8 Relation between RN of paint film deterioration and exposure time
P8 End part of span of main girder (External girder)
Lower surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=32)

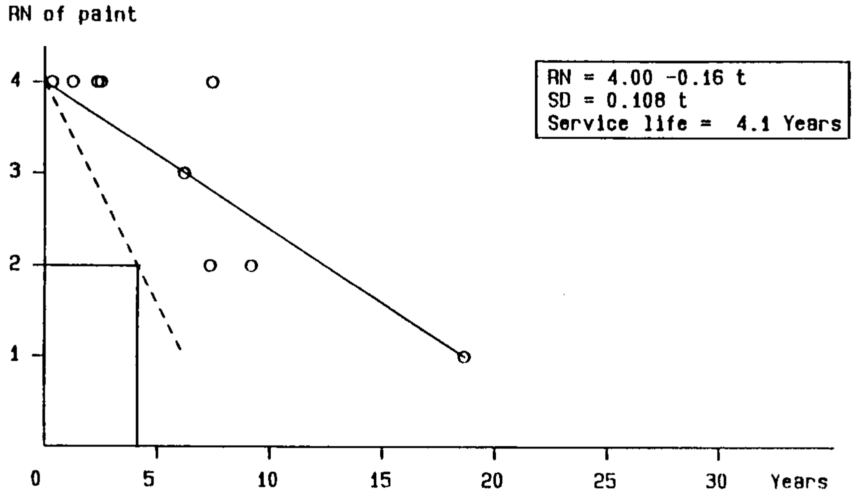

Fig. A2-9 Relation between RN of paint film deterioration and exposure time
P9 End part of span of main girder (Internal girder)
Shoe (City A, Rural envi.)
Paint type = Alkyd resins (N= 9)

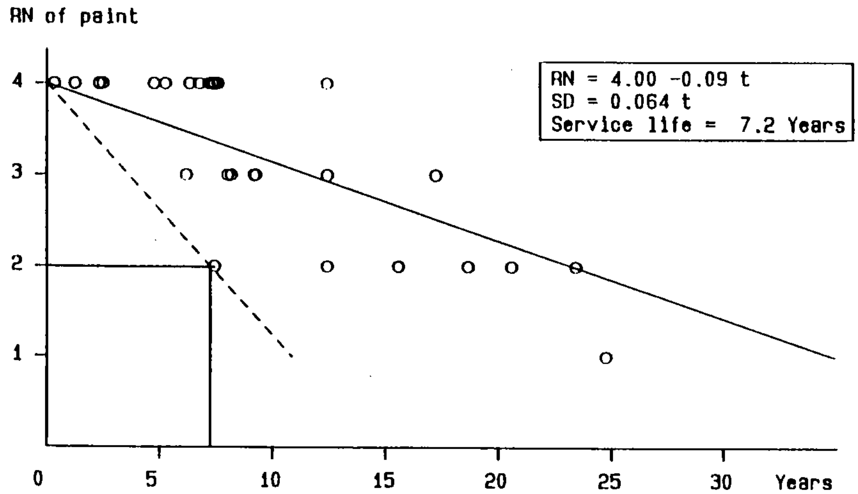

Fig. A2-10 Relation between RN of paint film deterioration and exposure time
P10 End part of span of main girder (Internal girder)
Lower surface of upper flange (City A, Rural envi.)
Paint type = Alkyd resins (N=29)

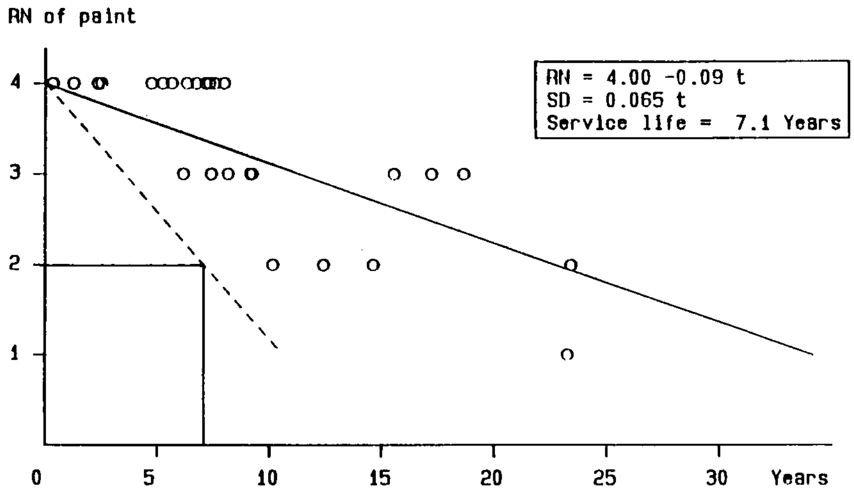

Fig. A2-11 Relation between RN of paint film deterioration and exposure time
P11 End part of span of main girder (Internal girder)
Web (City A, Rural envi.)
Paint type = Alkyd resins (N=30)

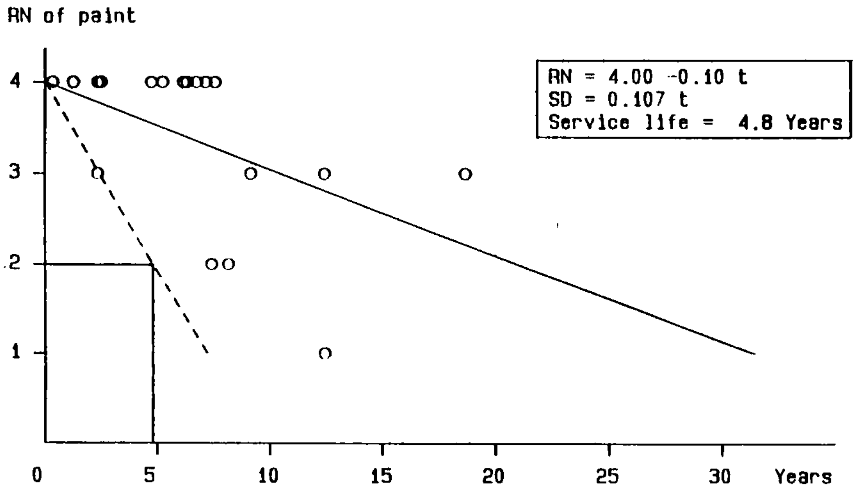

Fig. A2-12 Relation between RN of paint film deterioration and exposure time
P12 End part of span of main girder (Internal girder)
Upper surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=18)

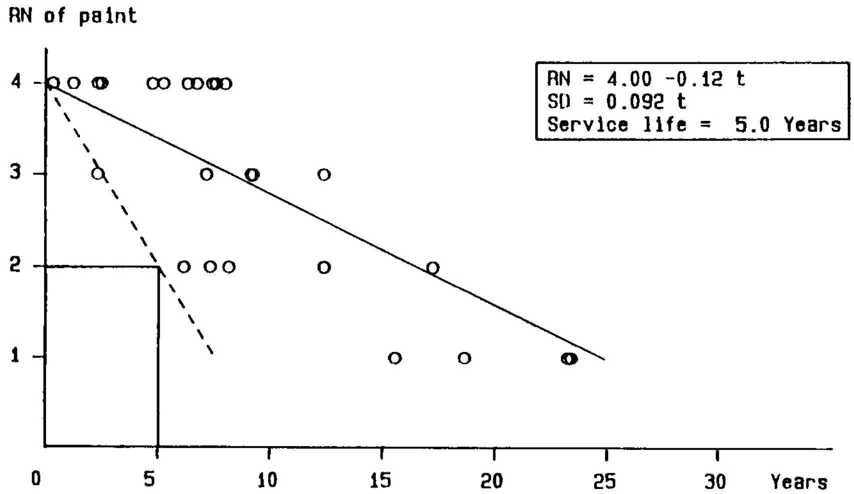

Fig. A2-13 Relation between RN of paint film deterioration and exposure time
P13 End part of span of main girder (Internal girder)
Lower surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=27)

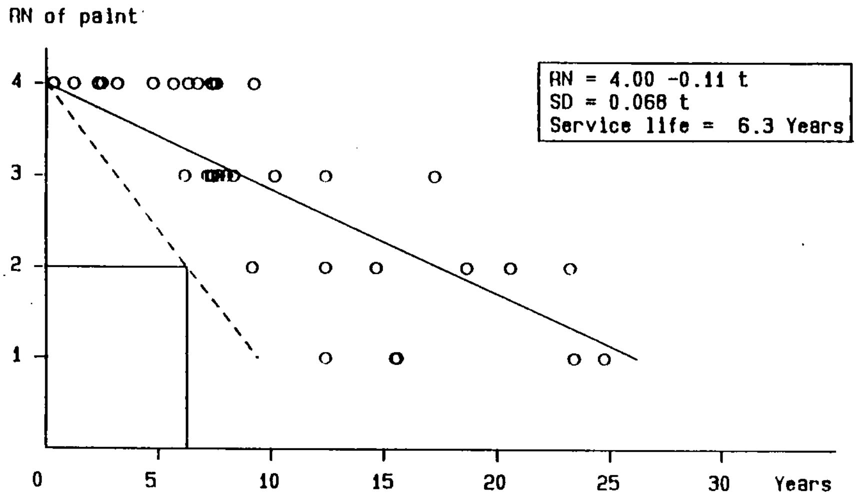

Fig. A2-14 Relation between RN of paint film deterioration and exposure time
P15 Middle part of span of main girder (External girder)
Lower surface of upper flange - Outer side (City A, Rural envi.)
Paint type = Alkyd resins (N=35)

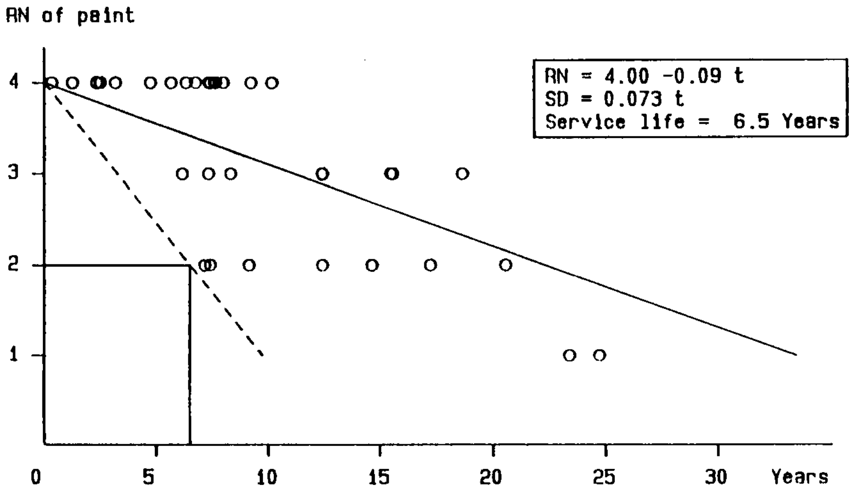

Fig. A2-15 Relation between RN of paint film deterioration and exposure time
P16 Middle part of span of main girder (External girder)
Lower surface of upper flange - Inner side (City A, Rural envi.)
Paint type = Alkyd resins (N=35)

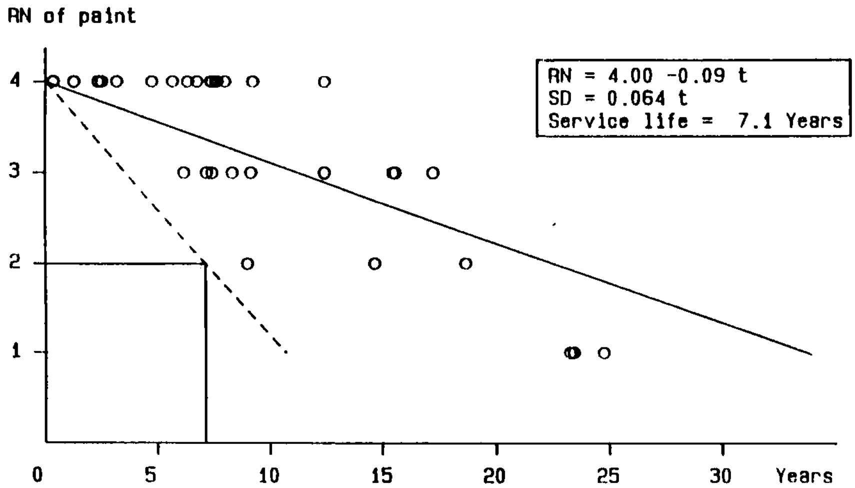

Fig. A2-16 Relation between RN of paint film deterioration and exposure time
P17 Middle part of span of main girder (External girder)
Web - Outer surface (City A, Rural envi.)
Paint type = Alkyd resins (N=34)

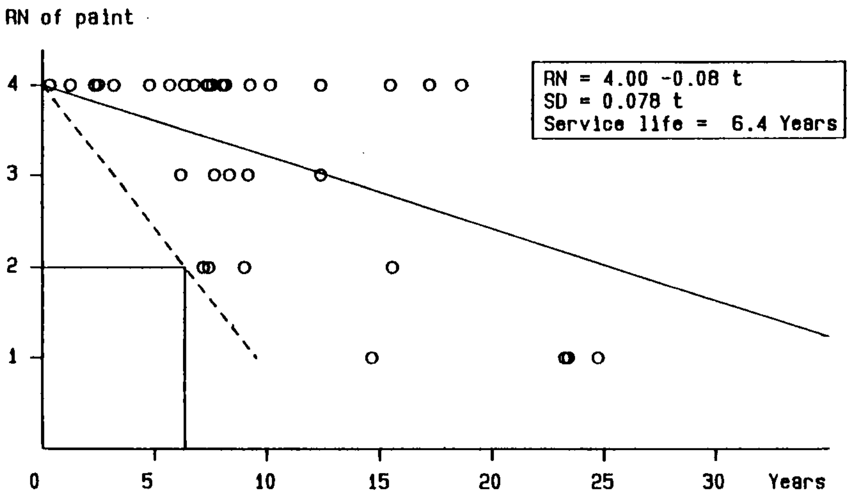

Fig. A2-17 Relation between RN of paint film deterioration and exposure time
P18 Middle part of span of main girder (External girder)
Web - Inner surface (City A. Rural envi.)
Paint type = Alkyd resins (N=37)

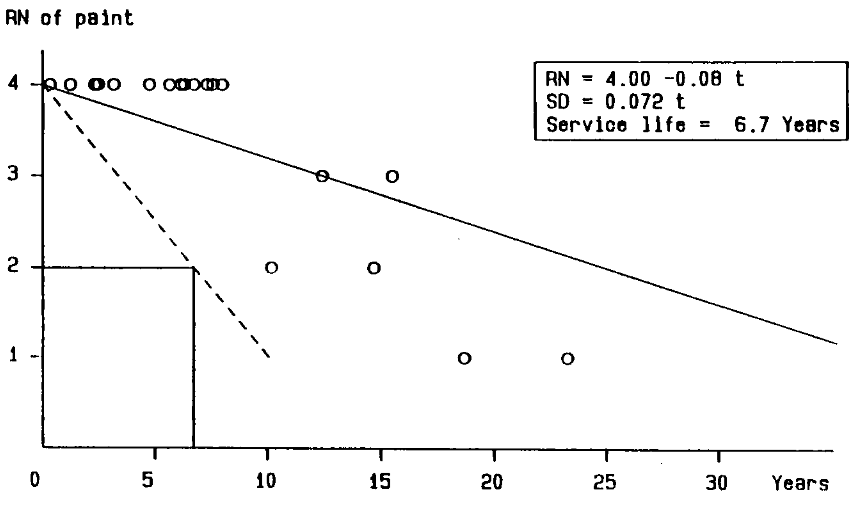

Fig. A2-18 Relation between RN of paint film deterioration and exposure time
P19 Middle part of span of main girder (External girder)
Upper surface of lower flange - Outer side (City A. Rural envi.)
Paint type = Alkyd resins (N=21)

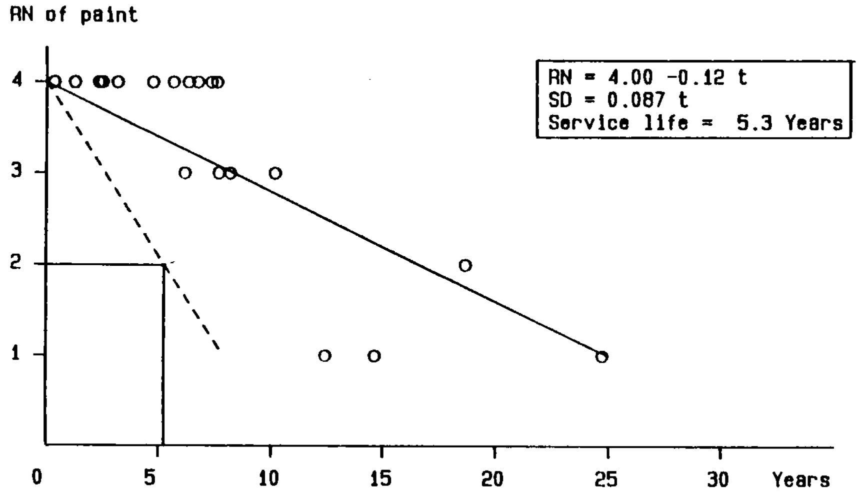

Fig. A2-19 Relation between RN of paint film deterioration and exposure time
P20 Middle part of span of main girder (External girder)
Upper surface of lower flange - Inner side (City A, Rural envi.)
Paint type = Alkyd resins (N=20)

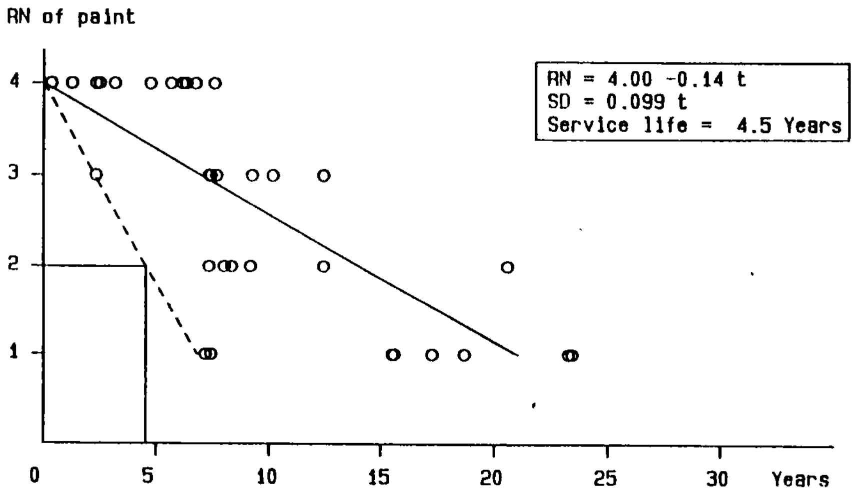

Fig. A2-20 Relation between RN of paint film deterioration and exposure time
P21 Middle part of span of main girder (External girder)
Lower surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=33)

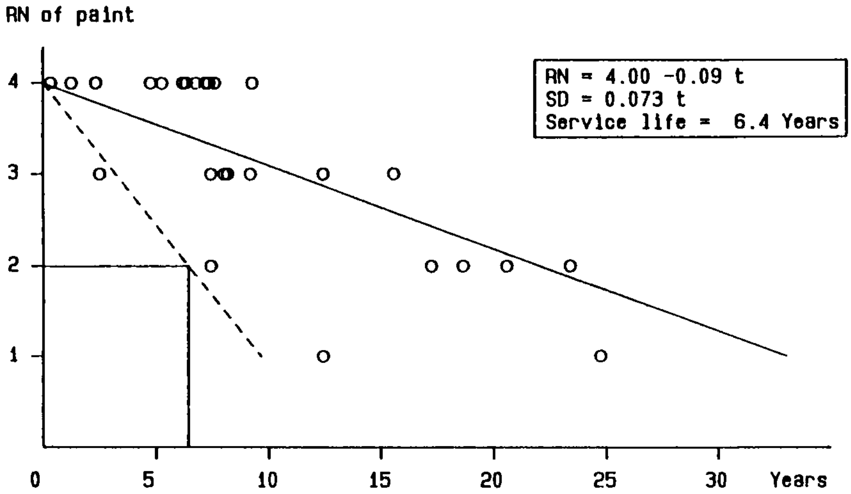

Fig. A2-21 Relation between RN of paint film deterioration and exposure time
P23 Middle part of span of main girder (Internal girder)
Lower surface of upper flange (City A, Rural envi.)
Paint type = Alkyd resins (N=29)

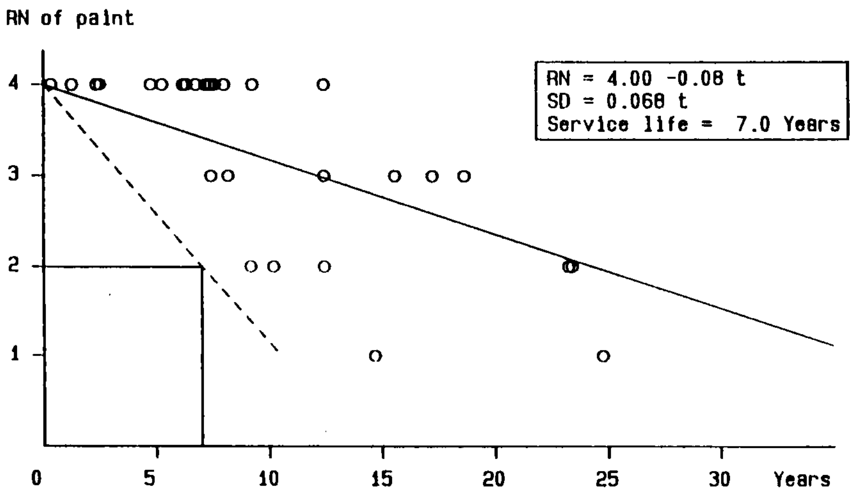

Fig. A2-22 Relation between RN of paint film deterioration and exposure time
P24 Middle part of span of main girder (Internal girder)
Web (City A, Rural envi.)
Paint type = Alkyd resins (N=31)

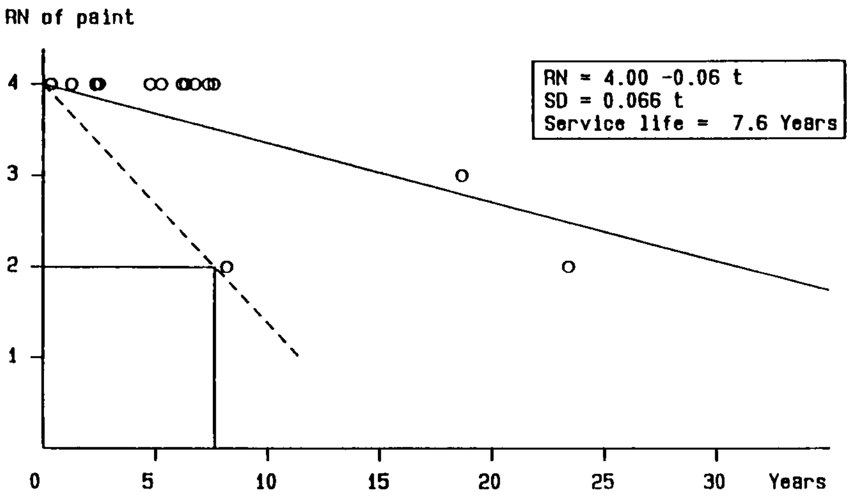

Fig. A2-23 Relation between RN of paint film deterioration and exposure time
P25 Middle part of span of main girder (Internal girder)
Upper surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=15)

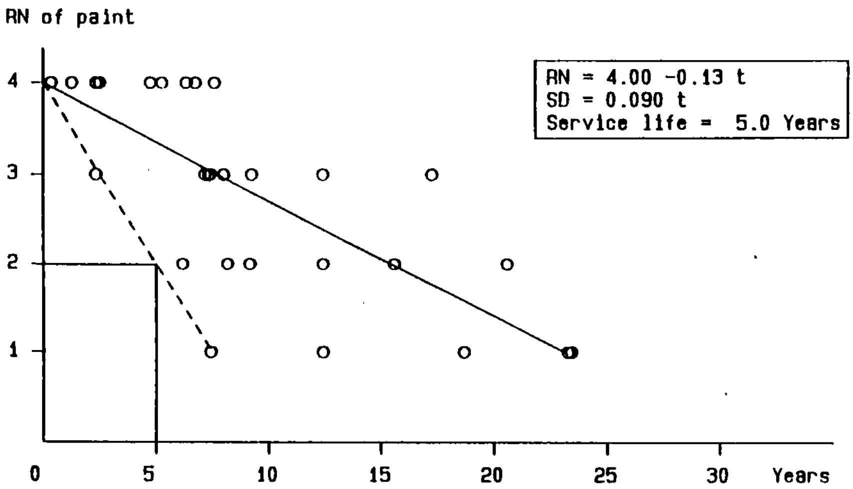

Fig. A2-24 Relation between RN of paint film deterioration and exposure time
P26 Middle part of span of main girder (Internal girder)
Lower surface of lower flange (City A, Rural envi.)
Paint type = Alkyd resins (N=28)

End part of span of main girders

	External girder	Internal girder
Shoe	2.0	4.1
Main girder	6.1 7.4 Outer side 8.2 6.6 Inner side 7.0 5.5 5.0	7.2 7.2 7.1 7.1 4.8 4.8 5.0

Middle part of span of main girders

	External girder	Internal girder
Main Girder	6.3 6.5 Outer side 7.1 6.4 Inner side 6.7 5.3 4.5	6.4 6.4 7.0 7.0 7.6 7.6 5.0
Expan. J.	-	-

Note ▒ : Members exposed to rain

Fig. A3-1 Service life of paint for road bridges in city A
Rural environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	6.8	6.8
Main girder	5.1 4.7 Outer Inner side 4.7 4.7 side – – 3.9	4.2 4.2 4.7 4.7 – – 5.1

Middle part of span of main girders

	External girder	Internal girder
Main Girder	5.1 4.7 Outer Inner side 5.1 4.7 side – – P21	4.2 4.2 4.6 4.6 – – 3.9
Expan. J.	–	–

Note ▒ : Members exposed to rain

Fig. A3-2 Service life of paint for road bridges in city B
Marine environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	2.6	5.1
Main girder	4.5 13.4 Outer Inner side 5.1 5.8 side – – 4.4	12.7 12.7 6.3 6.3 – – 4.2

Middle part of span of main girders

	External girder	Internal girder
Main Girder	4.5 4.5 Outer Inner side 5.6 5.0 side – – 12.2	4.2 4.2 4.2 4.2 – – –
Expan. J.	–	–

Note ░░ : Members exposed to rain

Fig. A3-3 Service life of paint for road bridges in city B
Marine environment, chlorinated rubber

End part of span of main girders

	External girder	Internal girder
Shoe	5.1	5.7
Main girder	4.8 5.0 Outer side 5.6 5.5 Inner side 5.1 5.4 4.8	5.6 5.6 5.2 5.2 6.4 6.4 5.4

Middle part of span of main girders

	External girder	Internal girder
Main Girder	5.0 5.0 Outer side 5.5 5.7 Inner side 5.4 6.2 5.1	5.2 5.2 5.5 5.5 5.3 5.3 5.3
Expan. J.	9.4	9.4

Note ░░ : Members exposed to rain

Fig. A3-4 Service life of paint for road bridges in city B
City environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	3.9	3.2
Main girder	5.6 3.6 Outer Inner side 6.4 1.4 side – – 5.0	4.4 4.4 5.0 5.0 – – 5.0

Middle part of span of main girders

	External girder	Internal girder
Main Girder	5.6 4.4 Outer Inner side 7.6 5.8 side – – 4.7	4.4 4.4 5.0 5.0 – – 5.0
Expan. J.	–	–

Note ░ : Members exposed to rain

Fig. A3-5 Service life of paint for road bridges in city B
City environment, chlorinated rubber

End part of span of main girders

	External girder	Internal girder
Shoe	2.8	2.3
Main girder	4.1 3.5 Outer Inner side 6.5 4.8 side 4.0 4.3 3.6	3.6 3.6 3.6 3.6 4.4 4.4 3.3

Middle part of span of main girders

	External girder	Internal girder
Main Girder	4.1 3.5 Outer Inner side 6.5 4.8 side 4.0 5.6 3.0	3.6 3.6 3.6 3.6 4.4 4.4 2.8
Expan. J.	-	-

Note : Members exposed to rain

Fig. A3-6 Service life of paint for road bridges in city C
Rural environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	3.6	3.6
Main girder	4.8 6.8 Outer Inner side 7.2 7.3 side 8.0 10.3 2.4	6.4 6.4 6.6 6.6 6.9 6.9 1.9

Middle part of span of main girders

	External girder	Internal girder
Main Girder	4.9 8.0 Outer Inner side 6.2 6.2 side 7.0 13.9 2.6	8.2 8.2 5.2 5.2 13.9 13.9 2.4
Expan. J.	-	-

Note : Members exposed to rain

Fig. A3-7 Service life of paint for road bridges in city C
Rural environment, chlorinated rubber

End part of span of main girders

	External girder	Internal girder
Shoe	4.6	4.7
Main girder	5.2 5.2 Outer Inner side 11.1 10.6 side – – 4.4	6.5 6.5 7.4 7.4 – – 4.8

Middle part of span of main girders

	External girder	Internal girder
Main Girder	6.7 9.3 Outer Inner side 7.1 8.7 side – – 4.3	7.4 7.4 10.5 10.5 – – 5.7
Expan. J.	–	–

Note : Members exposed to rain

Fig. A3-8 : Service life of paint for road bridges in city D
Marine environment, chlorinated rubber

End part of span of main girders

	External girder	Internal girder
Shoe	3.5	3.4
Main girder	6.6 5.1 Outer Inner side 7.4 10.6 side - - 3.9	6.3 6.3 9.3 9.3 - - 3.8

Middle part of span of main girders

	External girder	Internal girder
Main Girder	5.0 6.3 Outer Inner side 6.6 9.1 side - - 3.8	5.4 5.4 10.8 10.8 - - 3.7
Expan. J.	-	-

Note ░░ : Members exposed to rain

Fig. A3-9 Service life of paint for railway bridges in city E
City environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	3.4	-
Main girder	Outer side / Inner side 4.2 3.9 4.7 5.7 3.7 3.2 2.9	3.9 3.9 5.1 5.1 2.2 2.2 2.4

Middle part of span of main girders

	External girder	Internal girder
Main Girder	Outer side / Inner side 4.1 3.9 5.0 5.1 5.7 5.4 2.8	4.7 4.7 4.9 4.9 3.2 3.2 2.7
Expan. J.	-	-

Note ░ : Members exposed to rain

Fig. A3-10 Service life of paint for railway bridges in city E
Rural environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	2.5	3.1
Main girder	Outer side: 5.1, 5.7, 4.9 Inner side: 5.5, 6.1, 4.9 3.8	4.9, 6.8, 4.0 4.9, 6.8, 4.0 3.7

Middle part of span of main girders

	External girder	Internal girder
Main Girder	Outer side: 5.0, 6.0, 5.0 Inner side: 5.5, 6.7, 3.6 4.8	5.2, 6.0, 4.0 5.2, 6.0, 4.0 4.2
Expan. J.	-	-

Note ░░ : Members exposed to rain

Fig. A3-11 Service life of paint for road bridges in city F
Rural environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	1.6	1.1
Main girder	2.8 3.4 Outer Inner side 3.3 3.4 side 4.5 2.6 1.7	3.4 3.4 2.8 2.8 2.6 2.6 1.9

Middle part of span of main girders

	External girder	Internal girder
Main Girder	2.8 3.4 Outer Inner side 2.7 2.8 side 5.6 4.8 1.5	3.4 3.4 2.3 2.3 4.8 4.8 1.9
Expan. J.	-	-

Note ▒ : Members exposed to rain

Fig. A3-12 Service life of paint for road bridges in city G
Marine environment, alkyd resins

End part of span of main girders

	External girder	Internal girder
Shoe	2.2	2.5
Main girder	Outer side: 2.3 / 2.6 / 4.6 Inner side: 3.3 / 3.5 / 9.6 Bottom: 1.8	4.8 / 3.6 / 9.6 4.8 / 3.6 / 9.6 Bottom: 2.0

Middle part of span of main girders

	External girder	Internal girder
Main Girder	Outer side: 2.9 / 3.0 / 6.4 Inner side: 3.9 / 3.9 / 9.4 Bottom: 2.0	10.5 / 4.0 / 9.4 10.5 / 4.0 / 9.4 Bottom: 1.9
Expan. J.	-	-

Note ░░ : Members exposed to rain

Fig. A3-13 Service life of paint for road bridges in city G
Marine environment, chlorinated rubber

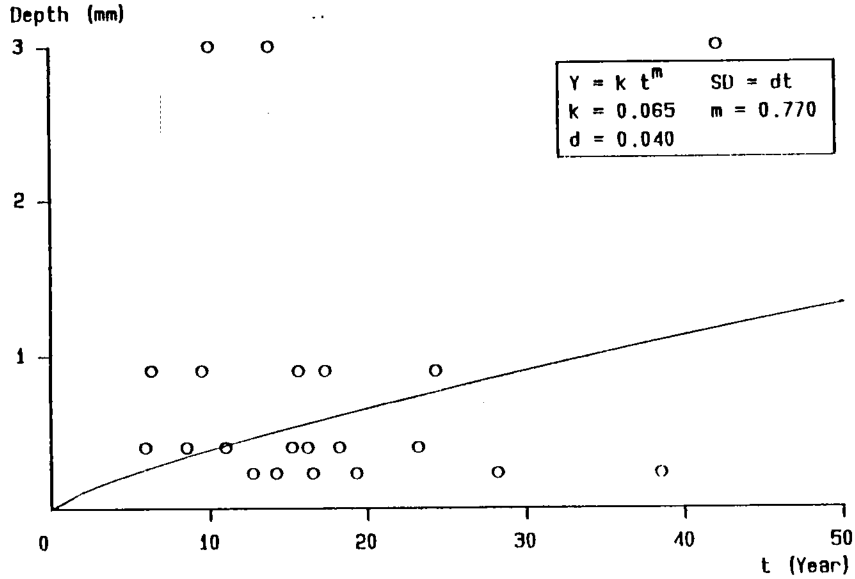

Fig. A4-1 Relation between corrosion depth and exposure time (Class 2)
P1 End part of span of main girder (External girder)
Shoe (City B, City envi.)
Exposure time = accumulated time after paint life

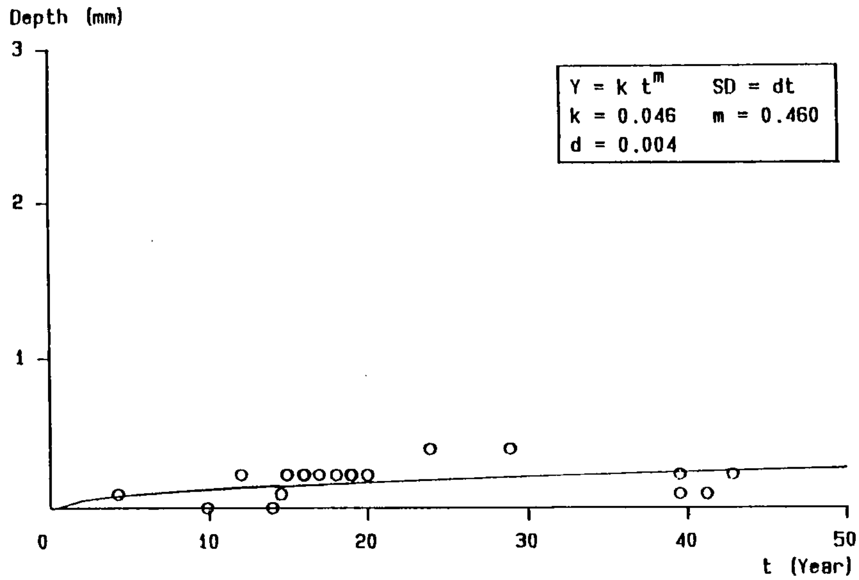

Fig. A4-2 Relation between corrosion depth and exposure time (Class 2)
P2 End part of span of main girder (External girder)
Lower surface of upper flange - Outer side (City B, City envi.)
Exposure time = accumulated time after paint life

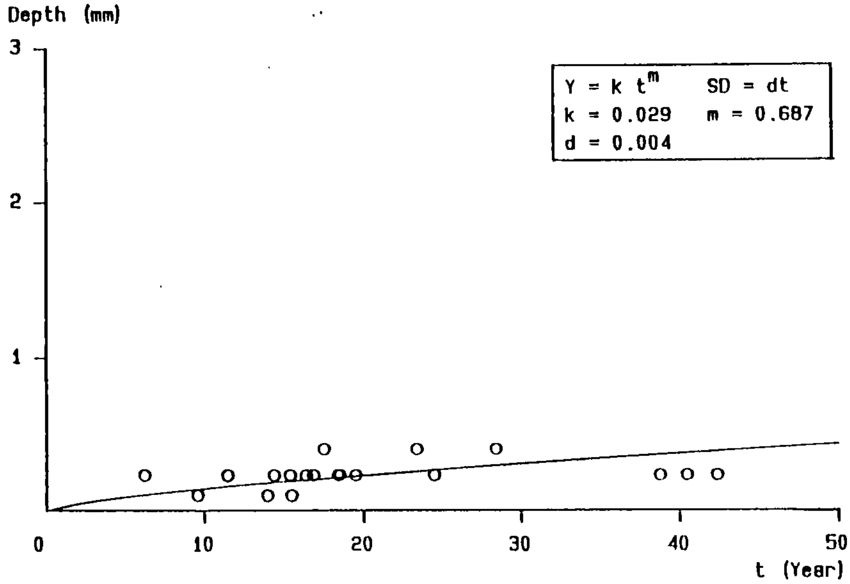

Fig. A4-3 Relation between corrosion depth and exposure time (Class 2)
P3 End part of span of main girder (External girder)
Lower surface of upper flange - Inner side (City B, City envi.)
Exposure time = accumulated time after paint life

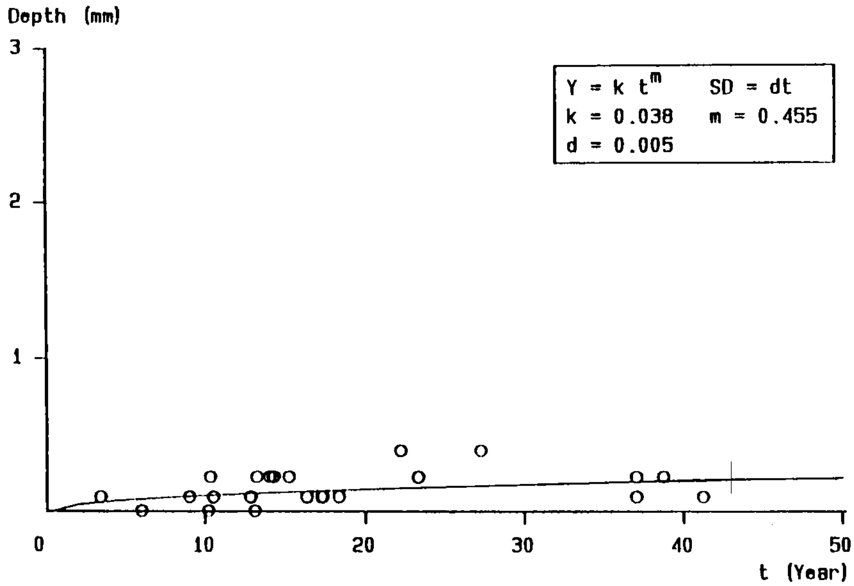

Fig. A4-4 Relation between corrosion depth and exposure time (Class 2)
P4 End part of span of main girder (External girder)
Web - Outer surface (City B, City envi.)
Exposure time = accumulated time after paint life

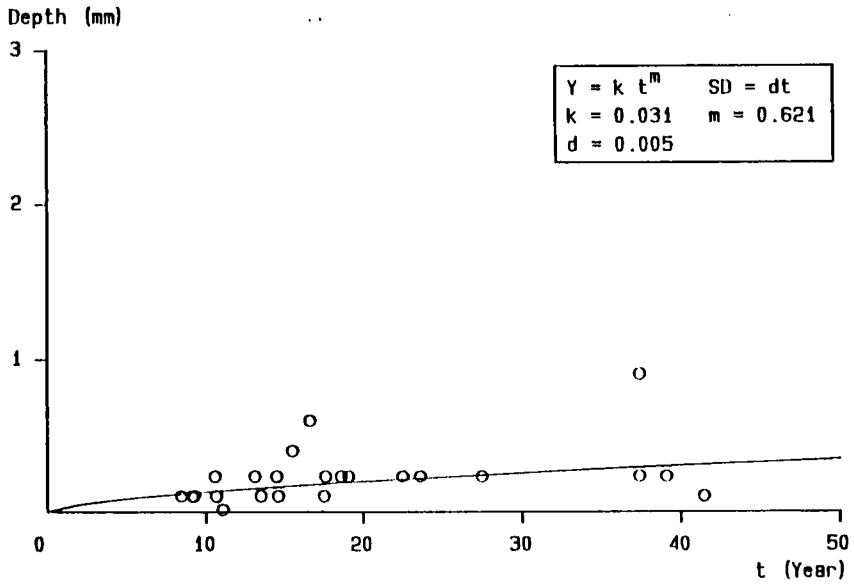

Fig. A4-5 Relation between corrosion depth and exposure time (Class 2)
P5 End part of span of main girder (External girder)
Web - Inner surface (City B, City envi.)
Exposure time = accumulated time after paint life

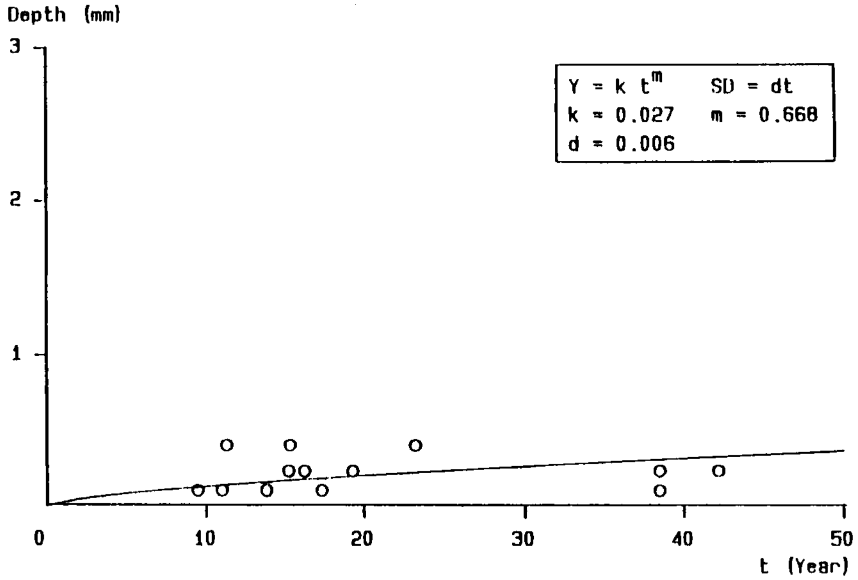

Fig. A4-6 Relation between corrosion depth and exposure time (Class 2)
P6 End part of span of main girder (External girder)
Upper surface of lower flange - Outer side (City B, City envi.)
Exposure time = accumulated time after paint life

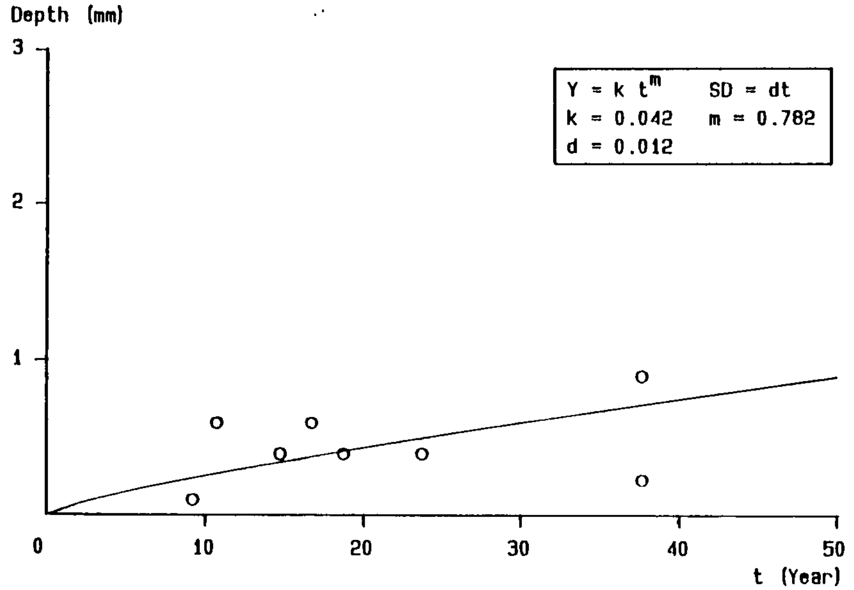

Fig. A4-7 Relation between corrosion depth and exposure time (Class 2)
P7 End part of span of main girder (External girder)
Upper surface of lower flange - Inner side (City B, City envi.)
Exposure time = accumulated time after paint life

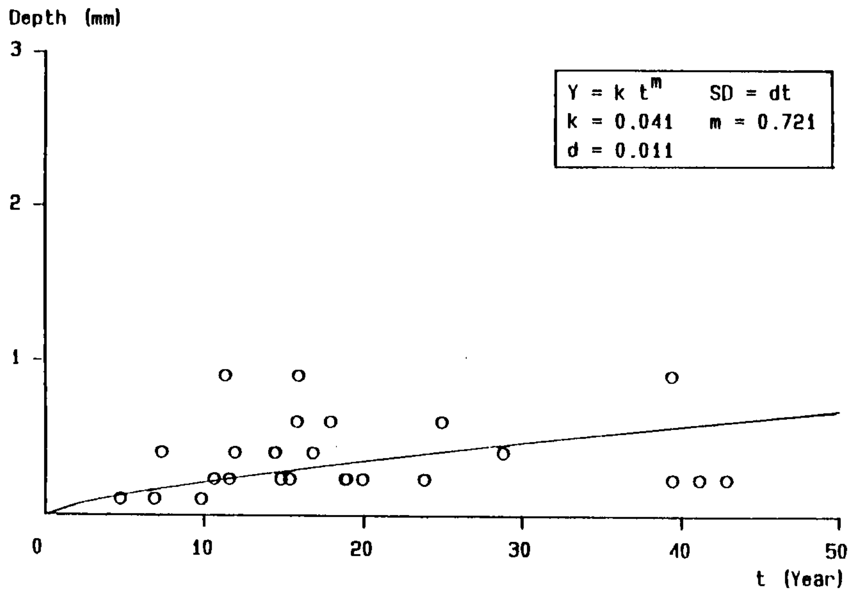

Fig. A4-8 Relation between corrosion depth and exposure time (Class 2)
P8 End part of span of main girder (External girder)
Lower surface of lower flange (City B, City envi.)
Exposure time = accumulated time after paint life

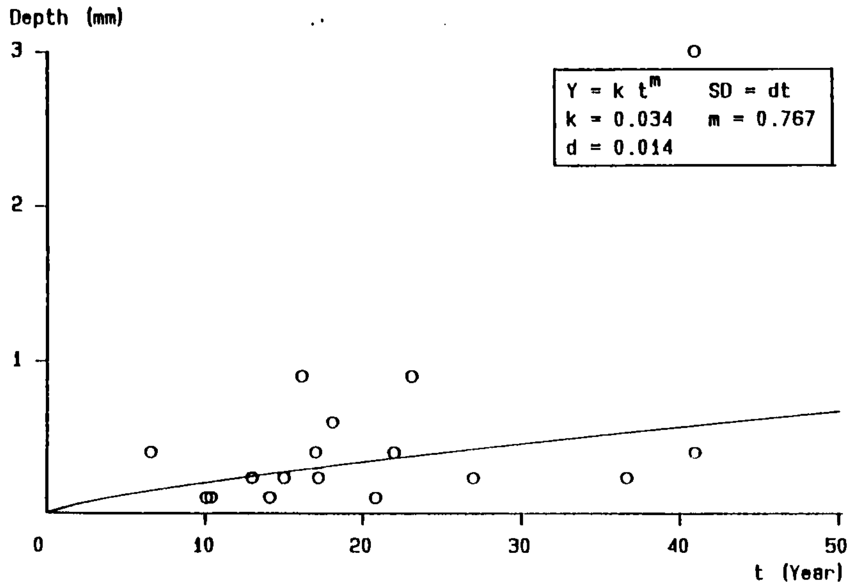

Fig. A4-9 Relation between corrosion depth and exposure time (Class 2)
P9 End part of span of main girder (Internal girder)
Shoe (City B, City envl.)
Exposure time = accumulated time after paint life

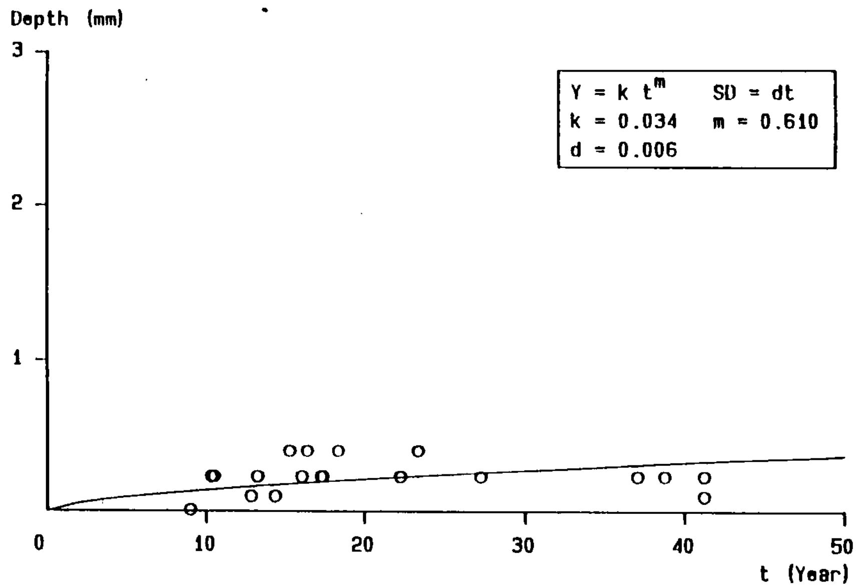

Fig. A4-10 Relation between corrosion depth and exposure time (Class 2)
P10 End part of span of main girder (Internal girder)
Lower surface of upper flange (City B, City envl.)
Exposure time = accumulated time after paint life

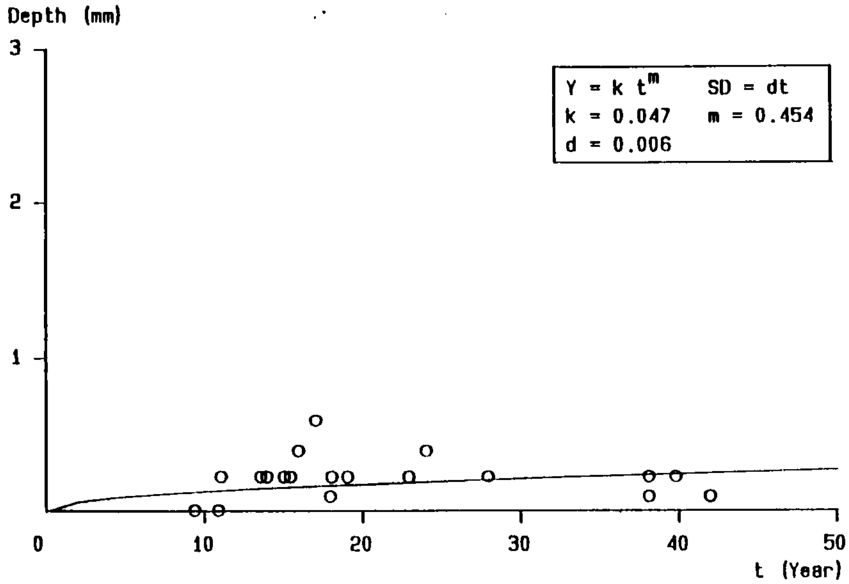

Fig. A4-11 Relation between corrosion depth and exposure time (Class 2)
P11 End part of span of main girder (Internal girder)
Web (City B, City envi.)
Exposure time = accumulated time after paint life

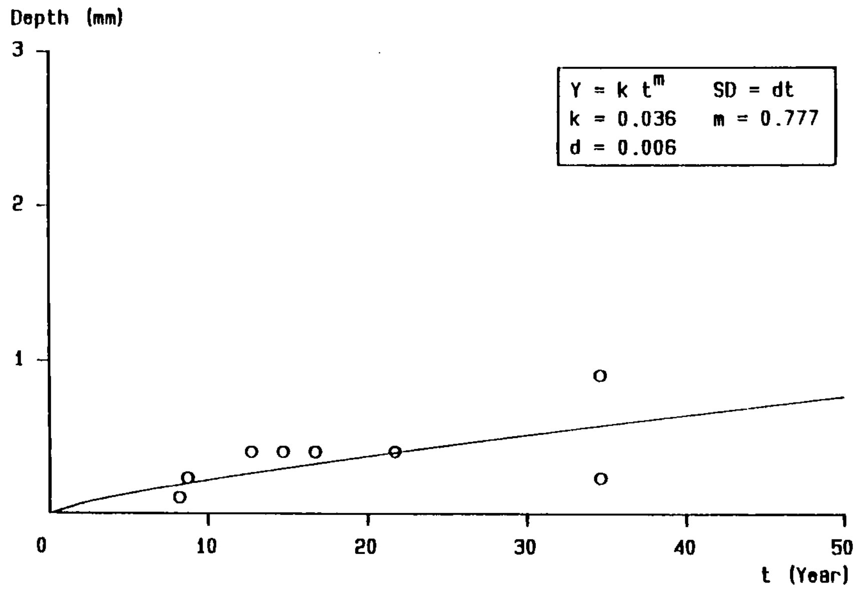

Fig. A4-12 Relation between corrosion depth and exposure time (Class 2)
P12 End part of span of main girder (Internal girder)
Upper surface of lower flange (City B, City envi.)
Exposure time = accumulated time after paint life

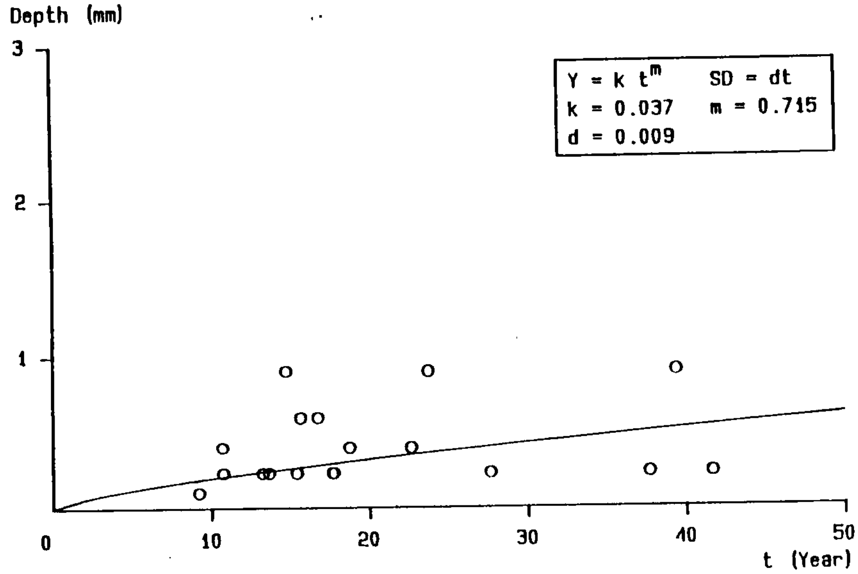

Fig. A4-13 Relation between corrosion depth and exposure time (Class 2)
P13 End part of span of main girder (Internal girder)
Lower surface of lower flange (City B, City envi.)
Exposure time = accumulated time after paint life

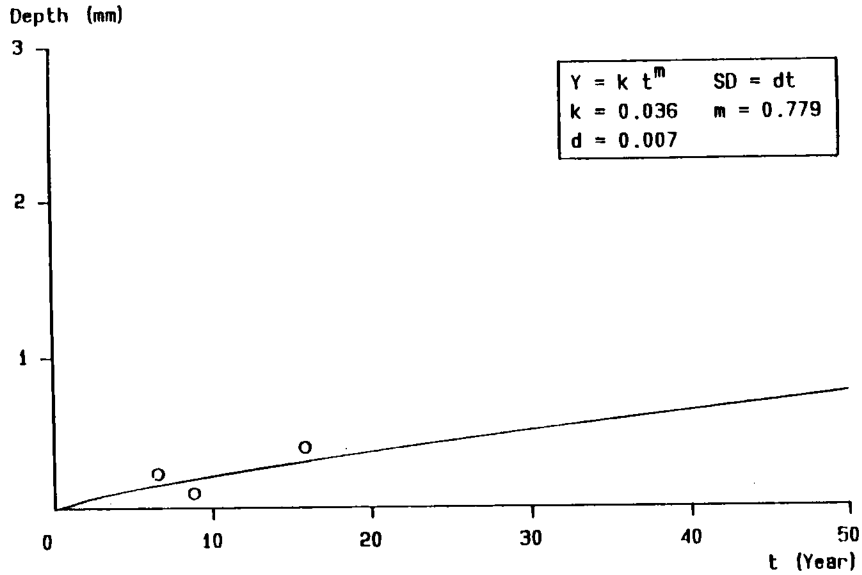

Fig. A4-14 Relation between corrosion depth and exposure time (Class 2)
P14 Middle part of span of main girder (External girder)
Expansion joint (City B, City envi.)
Exposure time = accumulated time after paint life

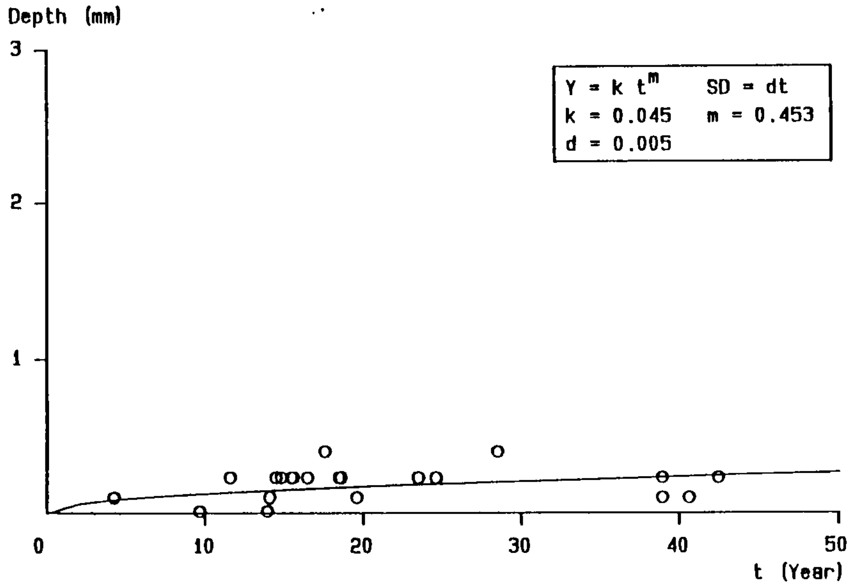

Fig. A4-15 Relation between corrosion depth and exposure time (Class 2)
P15 Middle part of span of main girder (External girder)
Lower surface of upper flange - Outer side (City B, City envi.)
Exposure time = accumulated time after paint life

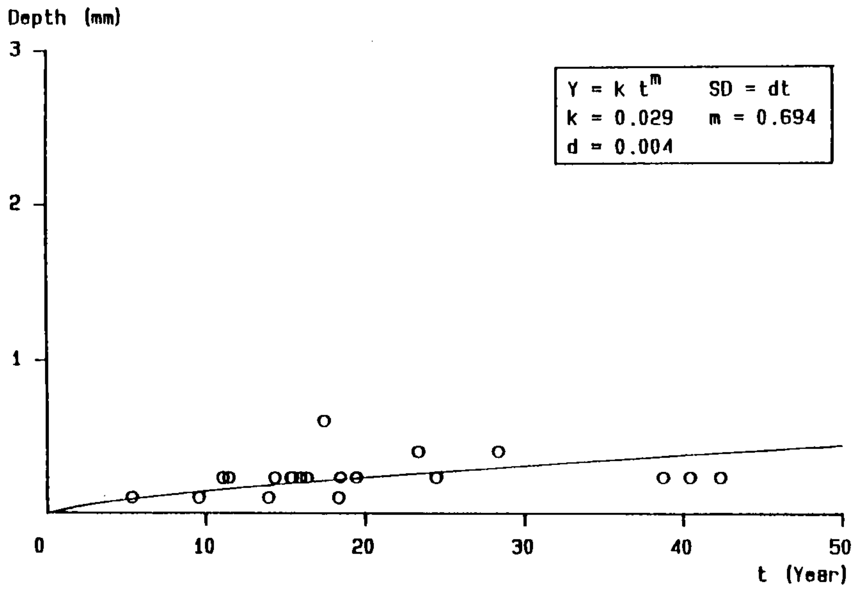

Fig. A4-16 Relation between corrosion depth and exposure time (Class 2)
P16 Middle part of span of main girder (External girder)
Lower surface of upper flange - Inner side (City B, City envi.)
Exposure time = accumulated time after paint life

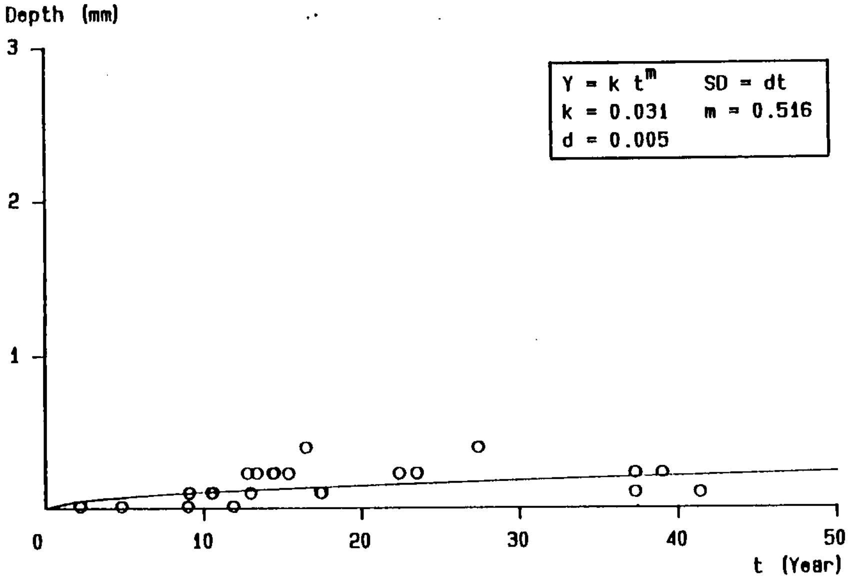

Fig. A4-17 Relation between corrosion depth and exposure time (Class 2)
P17 Middle part of span of main girder (External girder)
Web - Outer surface (City B, City envi.)
Exposure time = accumulaied time after paint life

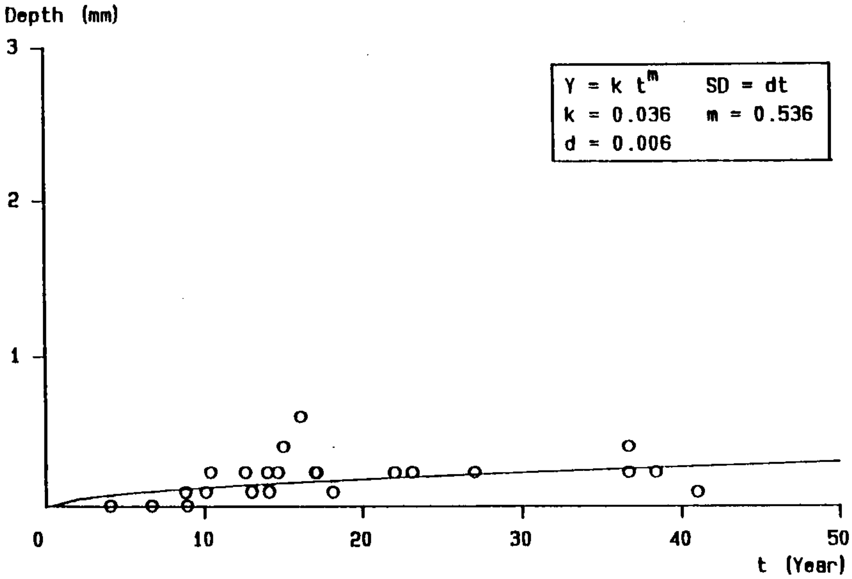

Fig. A4-18 Relation between corrosion depth and exposure time (Class 2)
P18 Middle part of span of main girder (External girder)
Web - Inner surface (City B, City envi.)
Exposure time = accumulaied time after paint life

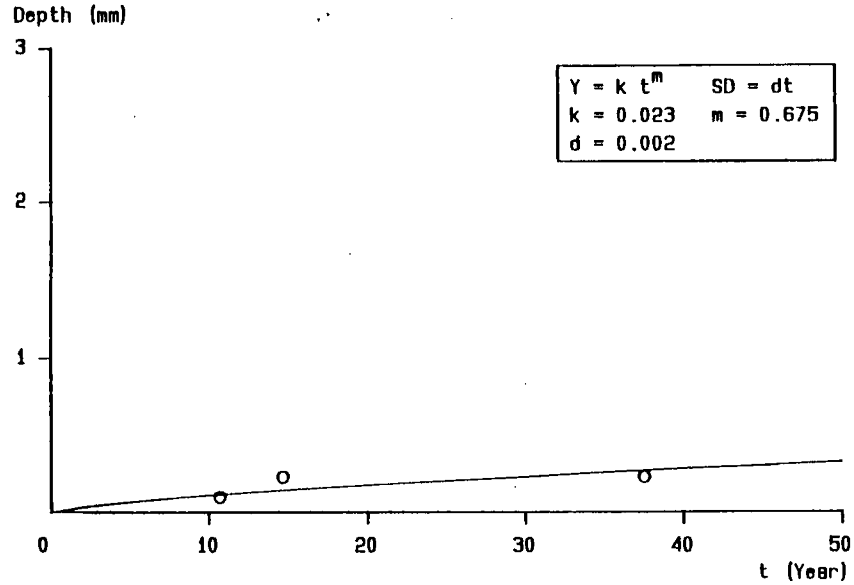

Fig. A4-19 Relation between corrosion depth and exposure time (Class 2)
P19 Middle part of span of main girder (External girder)
Upper surface of lower flange - Outer side (City B, City envi.)
Exposure time = accumulated time after paint life

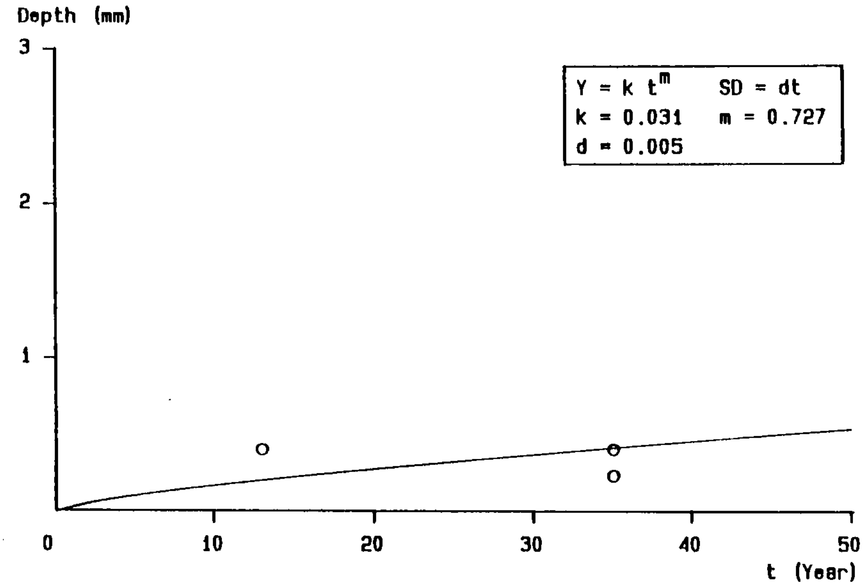

Fig. A4-20 Relation between corrosion depth and exposure time (Class 2)
P20 Middle part of span of main girder (External girder)
Upper surface of lower flange - Inner side (City B, City envi.)
Exposure time = accumulated time after paint life

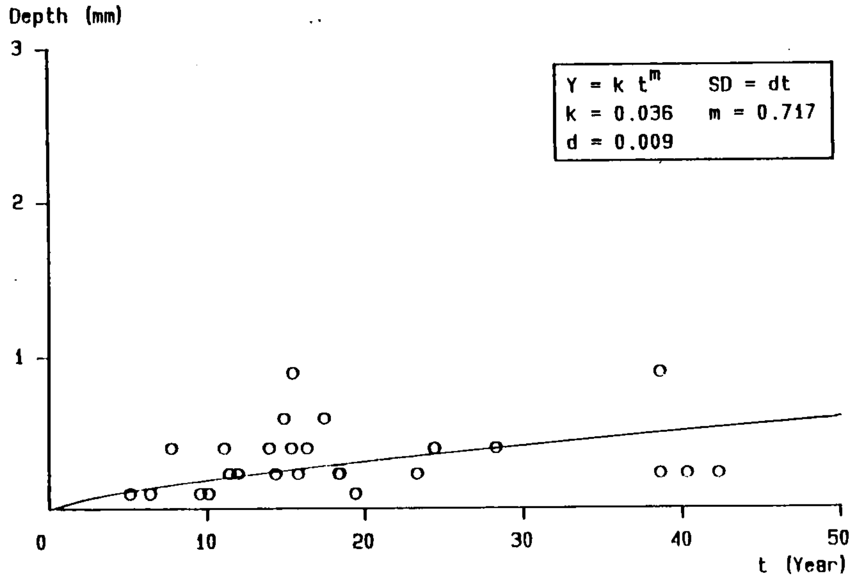

Fig. A4-21 Relation between corrosion depth and exposure time (Class 2)
P21 Middle part of span of main girder (External girder)
Lower surface of lower flange (City B, City envi.)
Exposure time = accumulated time after paint life

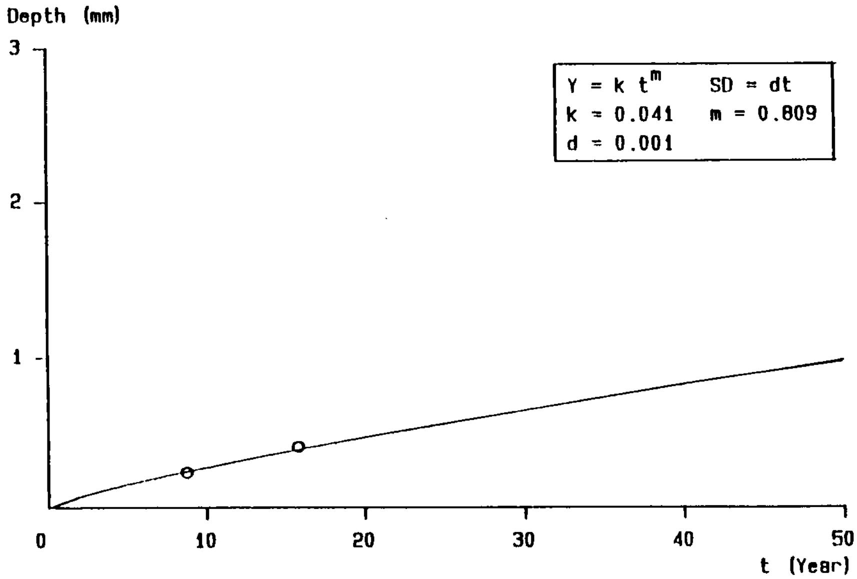

Fig. A4-22 Relation between corrosion depth and exposure time (Class 2)
P22 Middle part of span of main girder (Internal girder)
Expansion joint (City B, City envi.)
Exposure time = accumulated time after paint life

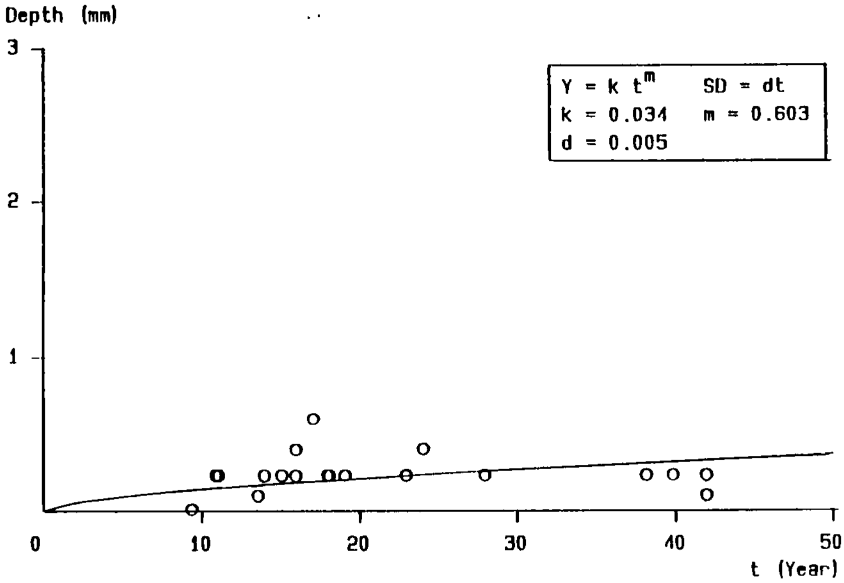

Fig. A4-23 Relation between corrosion depth and exposure time (Class 2)
P23 Middle part of span of main girder (Internal girder)
Lower surface of upper flange (City B, City envi.)
Exposure time = accumulated time after paint life

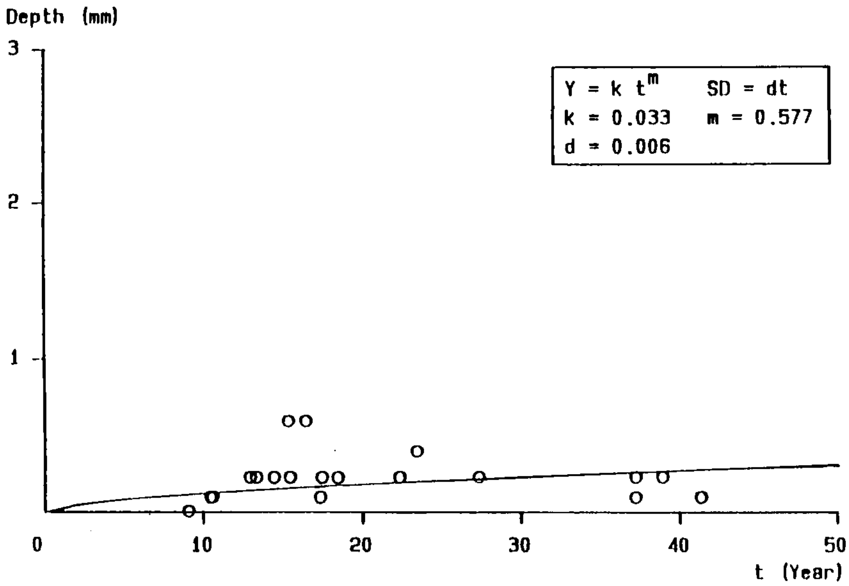

Fig. A4-24 Relation between corrosion depth and exposure time (Class 2)
P24 Middle part of span of main girder (Internal girder)
Web (City B, City envi.)
Exposure time = accumulated time after paint life

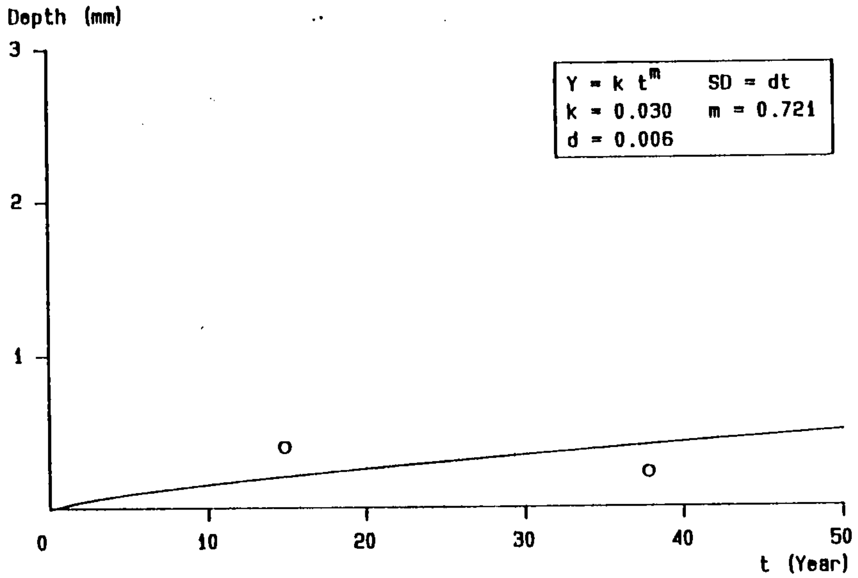

Fig. A4-25 Relation between corrosion depth and exposure time (Class 2)
P25 Middle part of span of main girder (Internal girder)
Upper surface of lower flange (City B, City envi.)
Exposure time = accumulated time after paint life

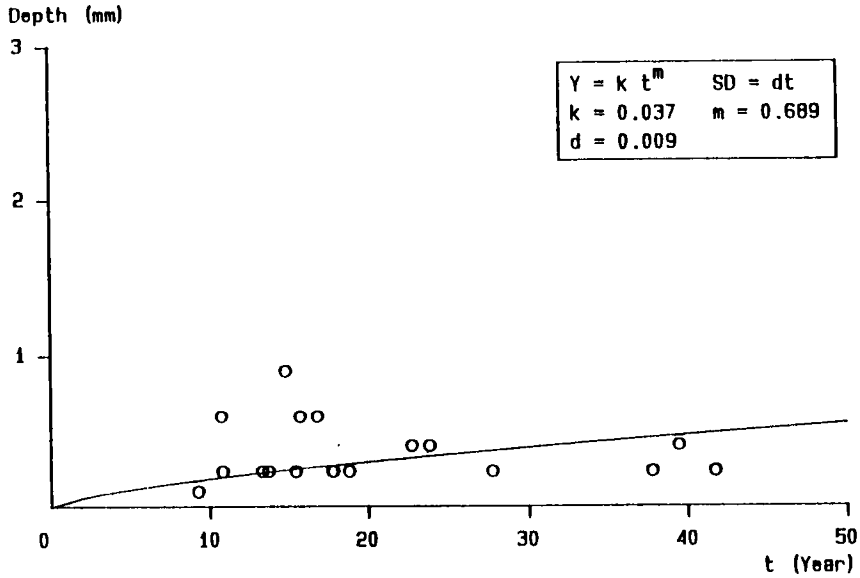

Fig. A4-26 Relation between corrosion depth and exposure time (Class 2)
P26 Middle part of span of main girder (Internal girder)
Lower surface of lower flange (City B, City envi.)
Exposure time = accumulated time after paint life

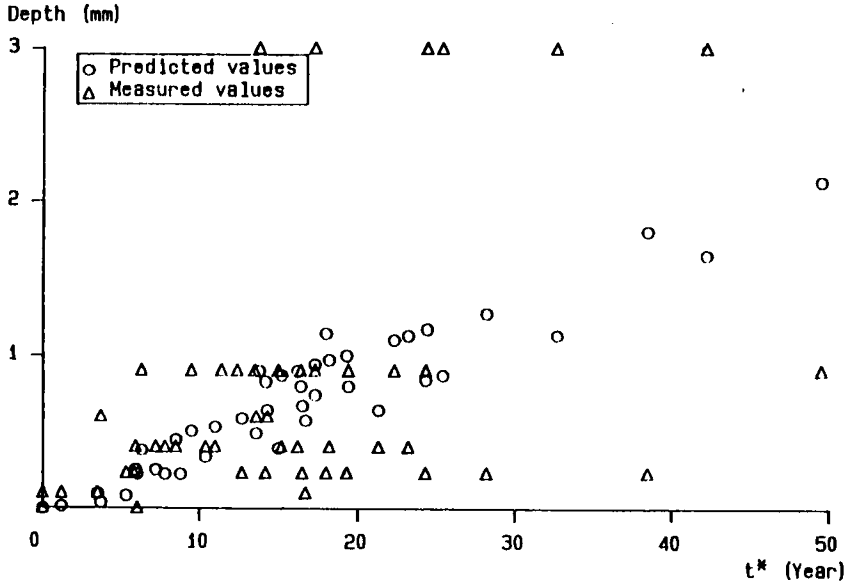

Fig. A5-1 Relation between corrosion depth and exposure time
P1 End part of span of main girder (External girder)
Shoe (Rural and city envi.)
Exposure time = accumulated time after paint life

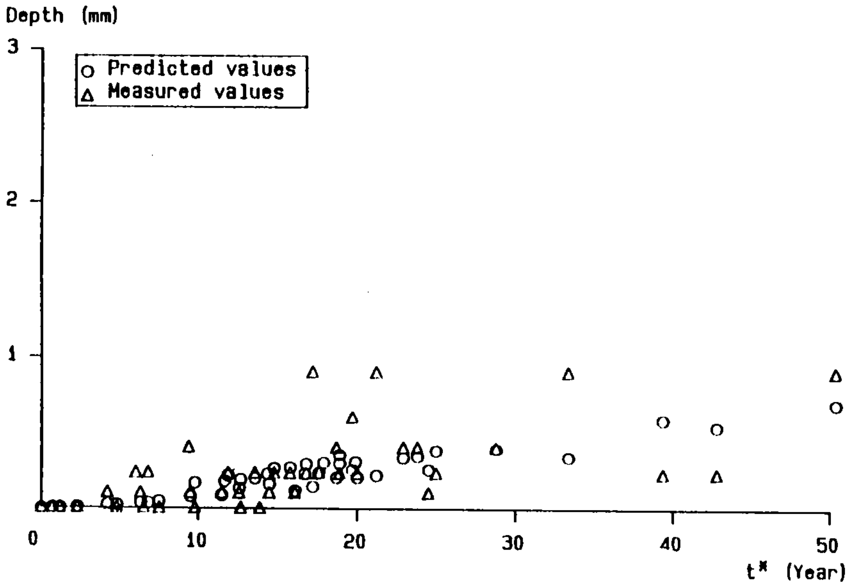

Fig. A5-2 Relation between corrosion depth and exposure time
P2 End part of span of main girder (External girder)
Lower surface of upper flange - Outer side (Rural and city envi.)
Exposure time = accumulated time after paint life

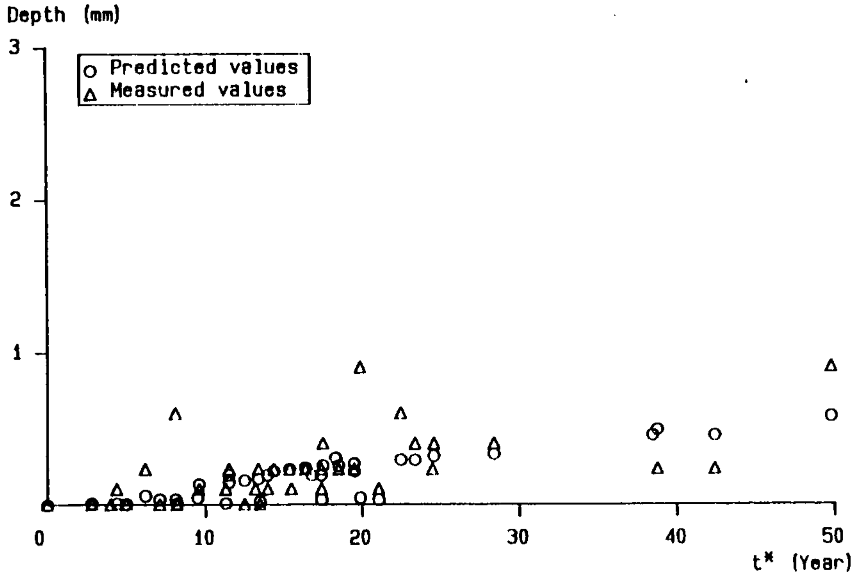

Fig. A5-3 Relation between corrosion depth and exposure time
P3 End part of span of main girder (External girder)
Lower surface of upper flange - Inner side (Rural and city envi.)
Exposure time = accumulated time after paint life

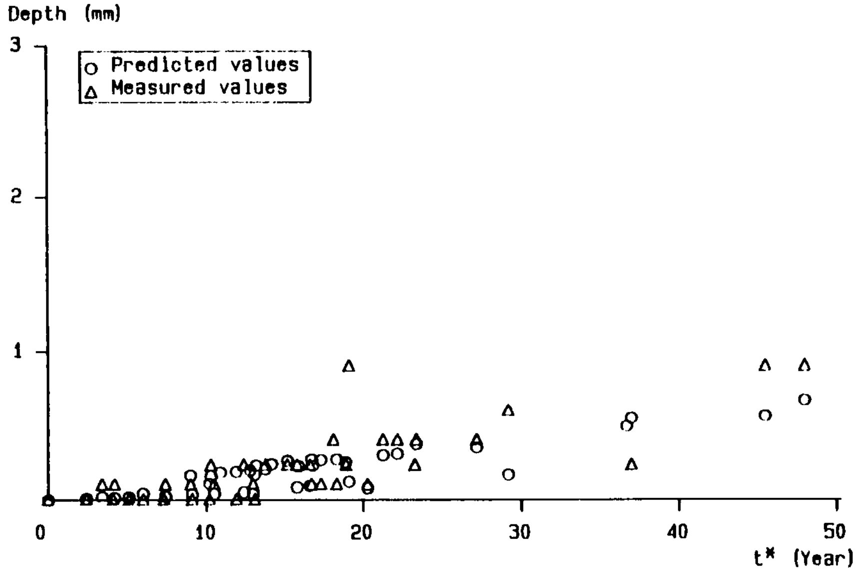

Fig. A5-4 Relation between corrosion depth and exposure time
P4 End part of span of main girder (External girder)
Web - Outer surface (Rural and city envi.)
Exposure time = accumulated time after paint life

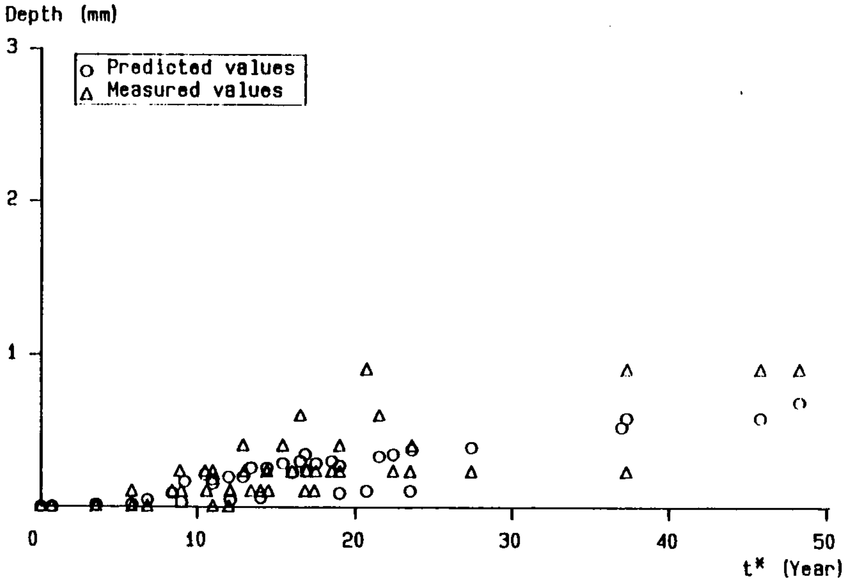

Fig. A5-5 Relation between corrosion depth and exposure time
P5 End part of span of main girder (External girder)
Web - Inner surface (Rural and city envi.)
Exposure time = accumulated time after paint life

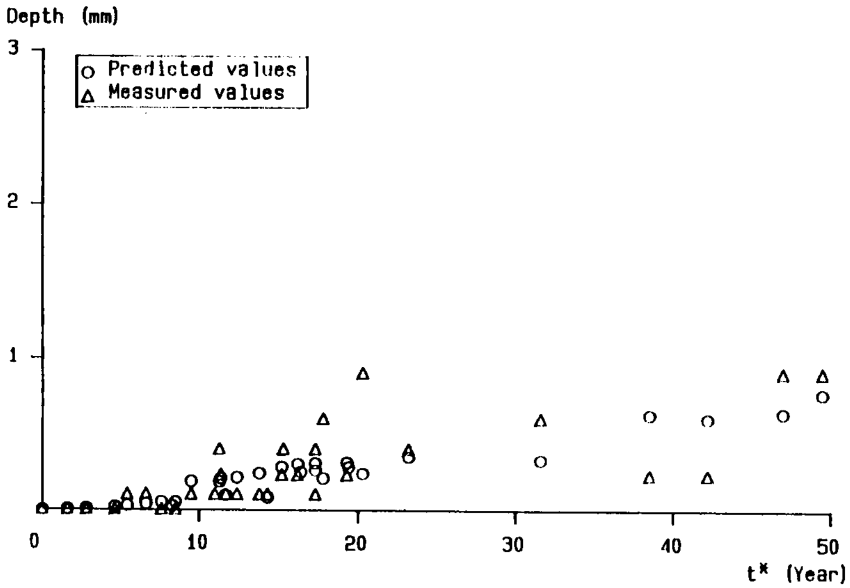

Fig. A5-6 Relation between corrosion depth and exposure time
P6 End part of span of main girder (External girder)
Upper surface of lower flange - Outer side (Rural and city envi.)
Exposure time = accumulated time after paint life

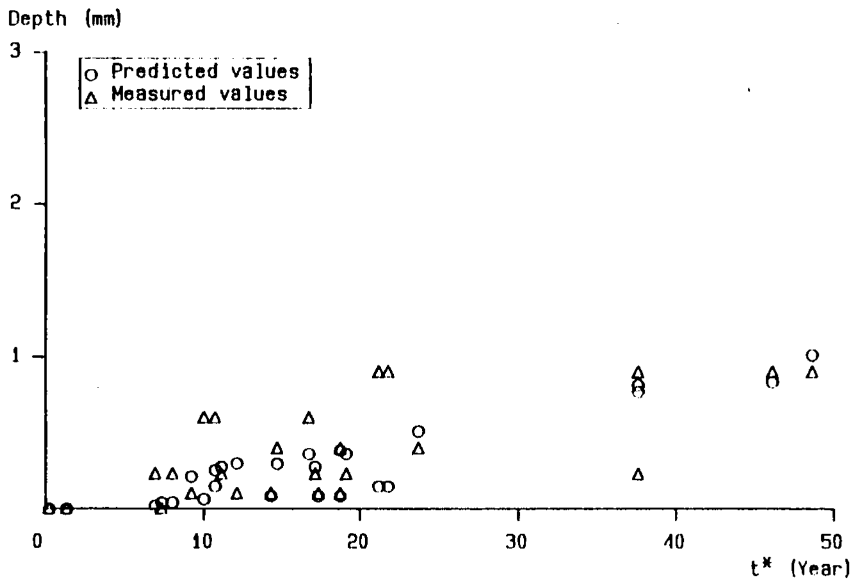

Fig. A5-7 Relation between corrosion depth and exposure time
P7 End part of span of main girder (External girder)
Upper surface of lower flange - Inner side (Rural and city envi.)
Exposure time = accumulated time after paint life

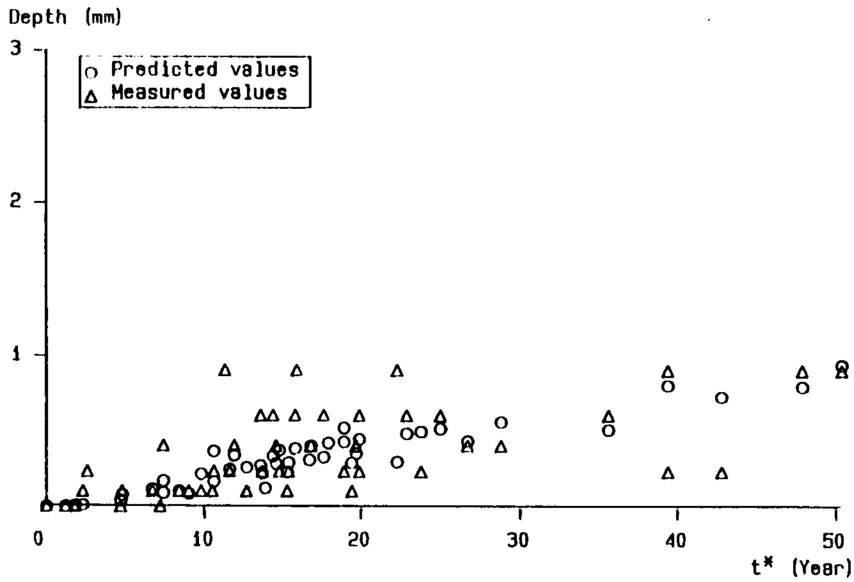

Fig. A5-8 Relation between corrosion depth and exposure time
P8 End part of span of main girder (External girder)
Lower surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

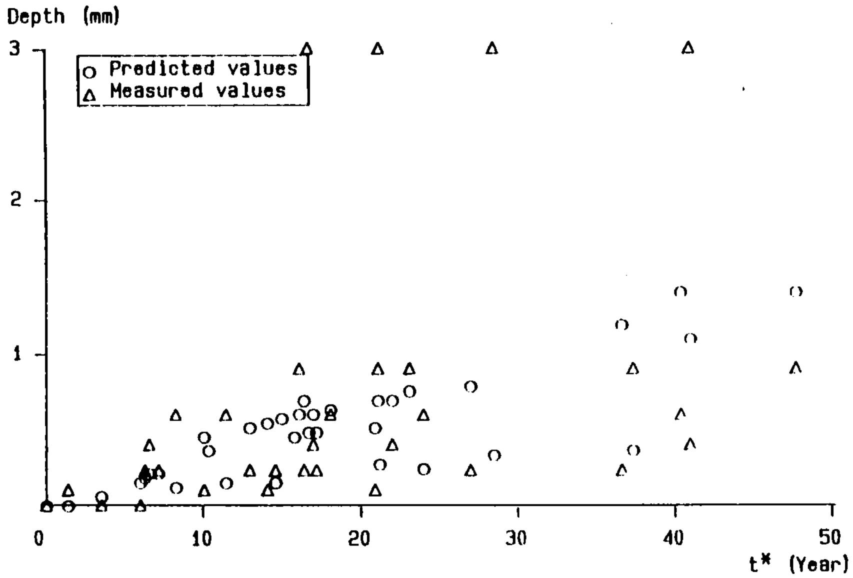

Fig. A5-9 Relation between corrosion depth and exposure time
P9 End part of span of main girder (Internal girder)
Shoe (Rural and city envi.)
Exposure time = accumulated time after paint life

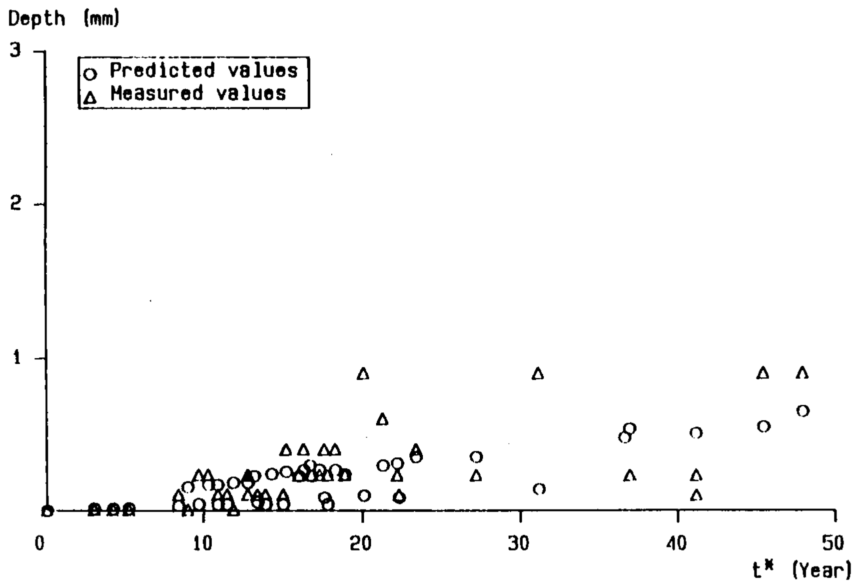

Fig. A5-10 Relation between corrosion depth and exposure time
P10 End part of span of main girder (Internal girder)
Lower surface of upper flange (Rural and city envi.)
Exposure time = accumulated time after paint life

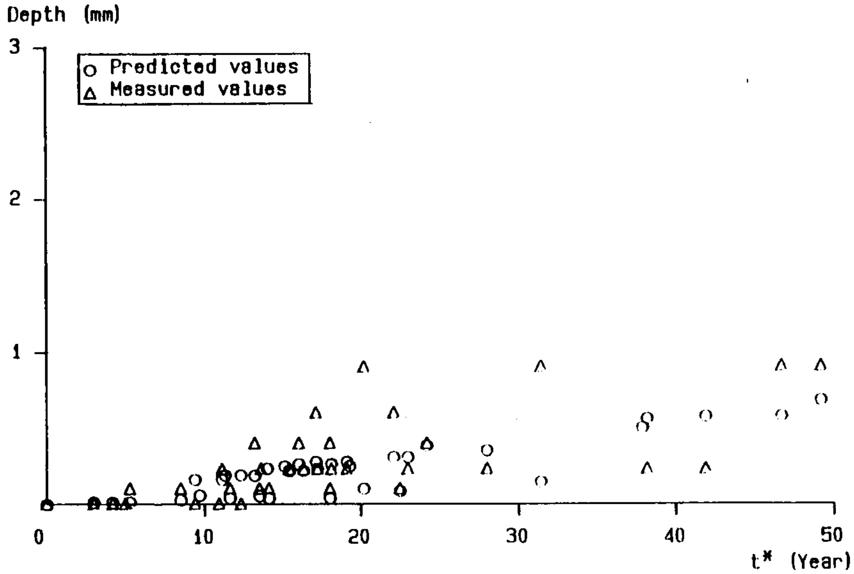

Fig. A5-11 Relation between corrosion depth and exposure time
P11 End part of span of main girder (Internal girder)
Web (Rural and city envi.)
Exposure time = accumulated time after paint life

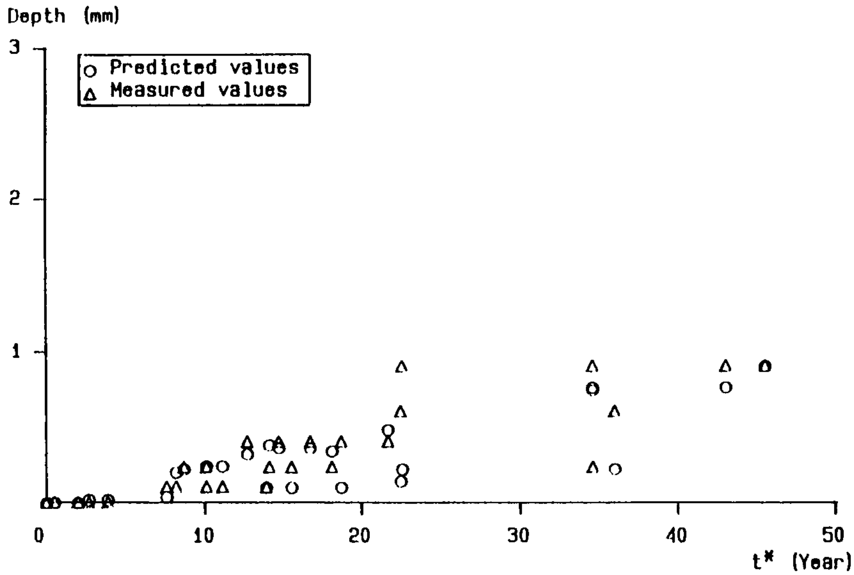

Fig. A5-12 Relation between corrosion depth and exposure time
P12 End part of span of main girder (Internal girder)
Upper surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

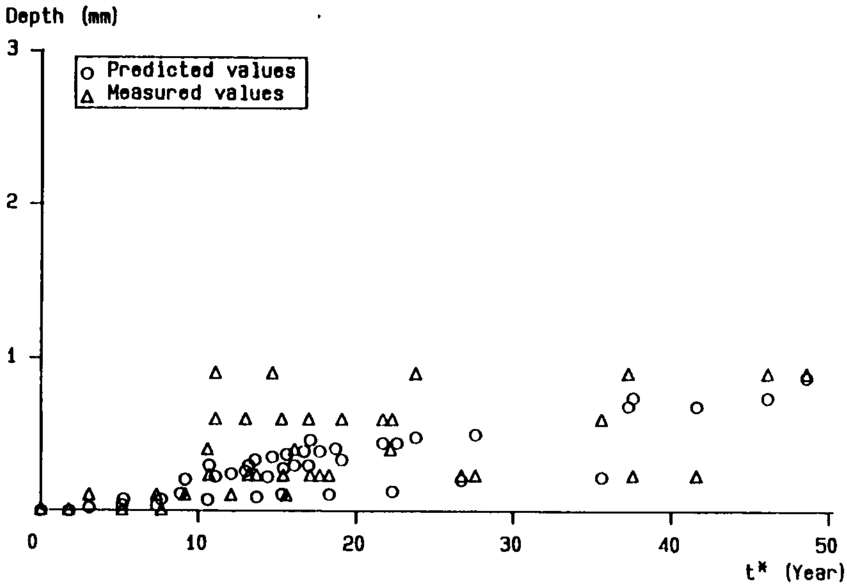

Fig. A5-13 Relation between corrosion depth and exposure time
P13 End part of span of main girder (Internal girder)
Lower surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

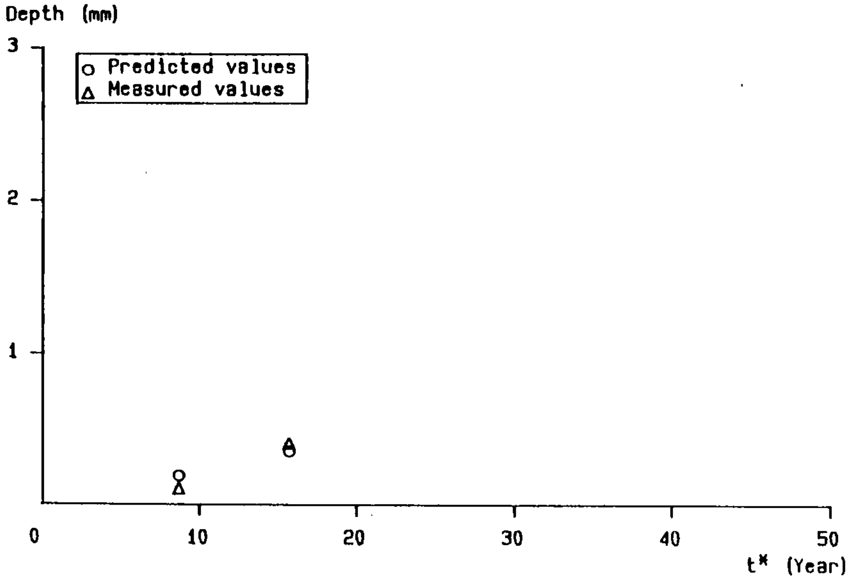

Fig. A5-14 Relation between corrosion depth and exposure time
P14 Middle part of span of main girder (External girder)
Expansion joint (Rural and city envi.)
Exposure time = accumulated time after paint life

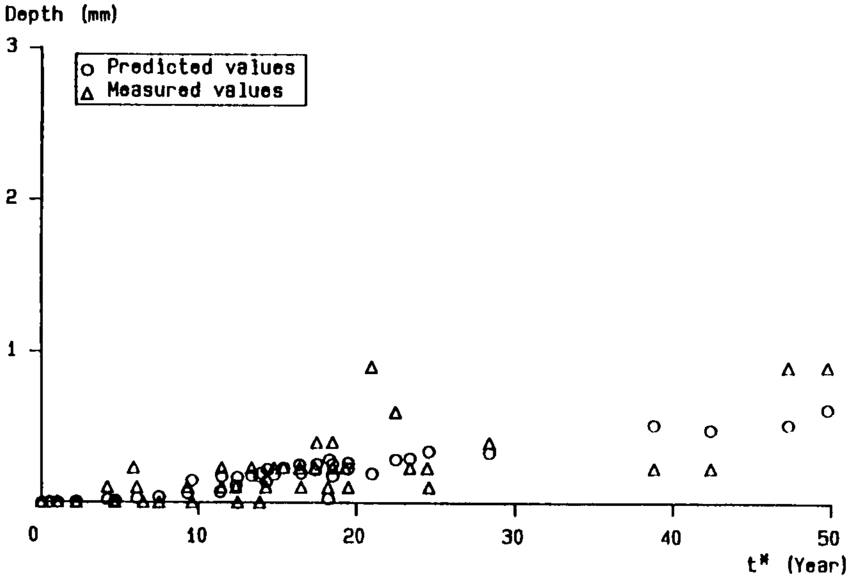

Fig. A5-15 Relation between corrosion depth and exposure time
P15 Middle part of span of main girder (External girder)
Lower surface of upper flange - Outer side (Rural and city envi.)
Exposure time = accumulated time after paint life

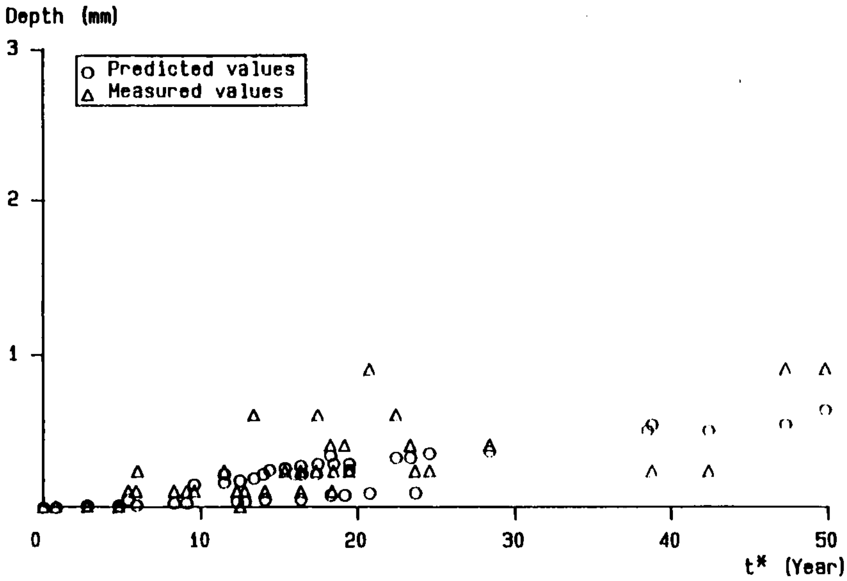

Fig. A5-16 Relation between corrosion depth and exposure time
P16 Middle part of span of main girder (External girder)
Lower surface of upper flange - Inner side (Rural and city envi.)
Exposure time = accumulated time after paint life

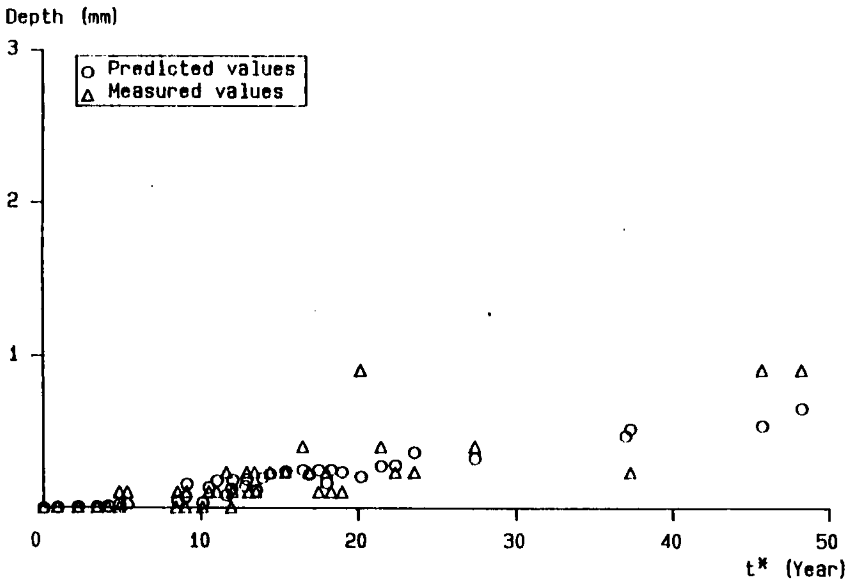

Fig. A5-17 Relation between corrosion depth and exposure time
P17 Middle part of span of main girder (External girder)
Web - Outer surface (Rural and city envi.)
Exposure time = accumulated time after paint life

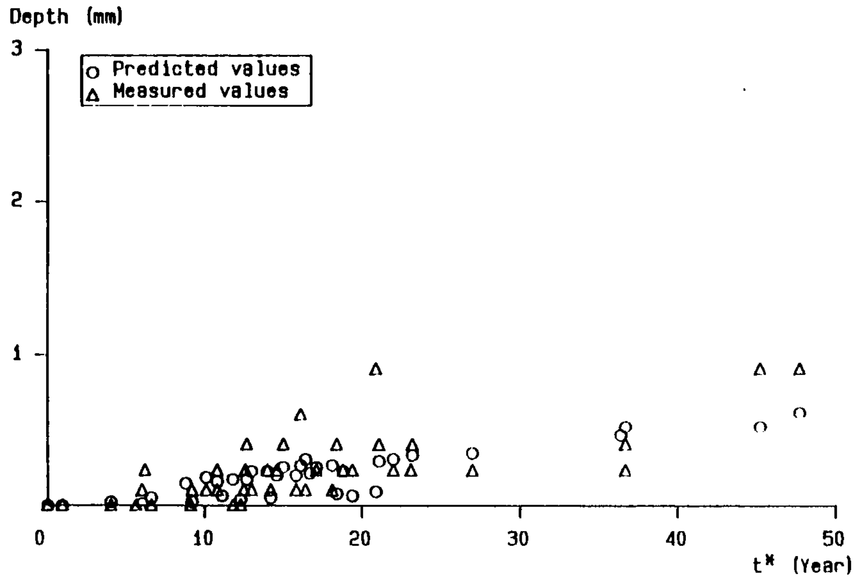

Fig. A5-18 Relation between corrosion depth and exposure time
P18 Middle part of span of main girder (External girder)
Web - Inner surface (Rural and city envi.)
Exposure time = accumulated time after paint life

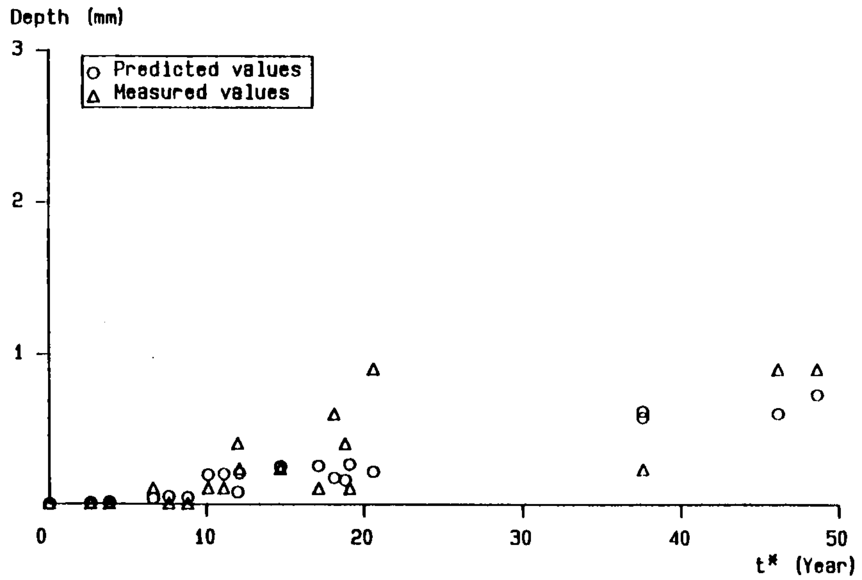

Fig. A5-19 Relation between corrosion depth and exposure time
P19 Middle part of span of main girder (External girder)
Upper surface of lower flange - Outer side (Rural and city envi.)
Exposure time = accumulated time after paint life

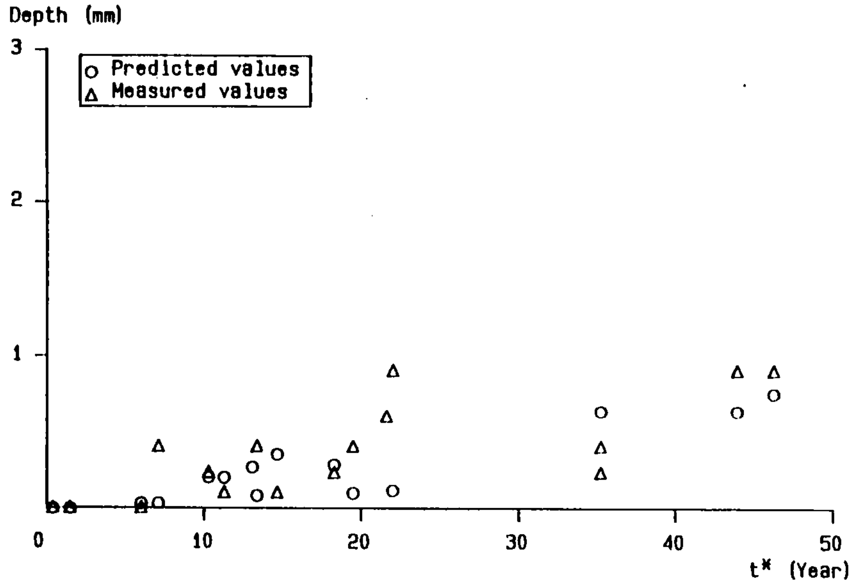

Fig. A5-20 Relation between corrosion depth and exposure time
P20 Middle part of span of main girder (External girder)
Upper surface of lower flange - Inner side (Rural and city envi.)
Exposure time = accumulated time after paint life

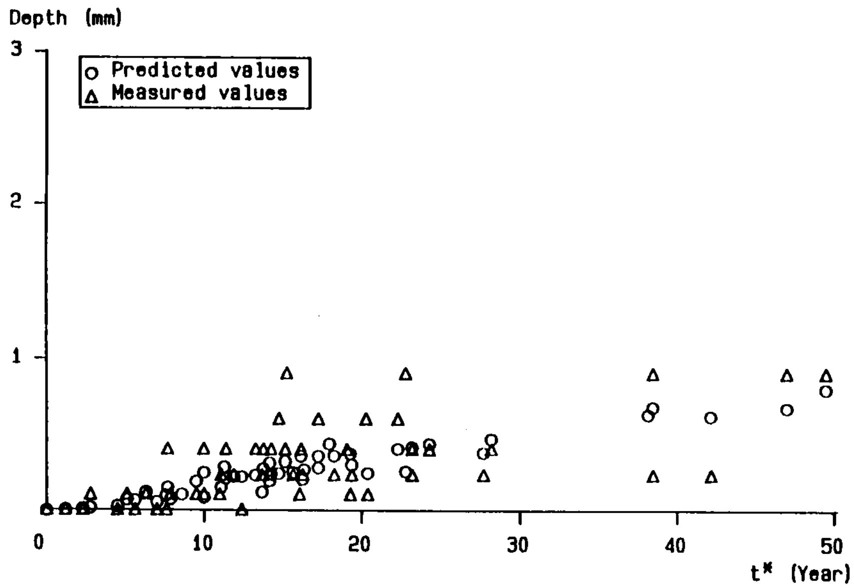

Fig. A5-21 Relation between corrosion depth and exposure time
P21 Middle part of span of main girder (External girder)
Lower surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

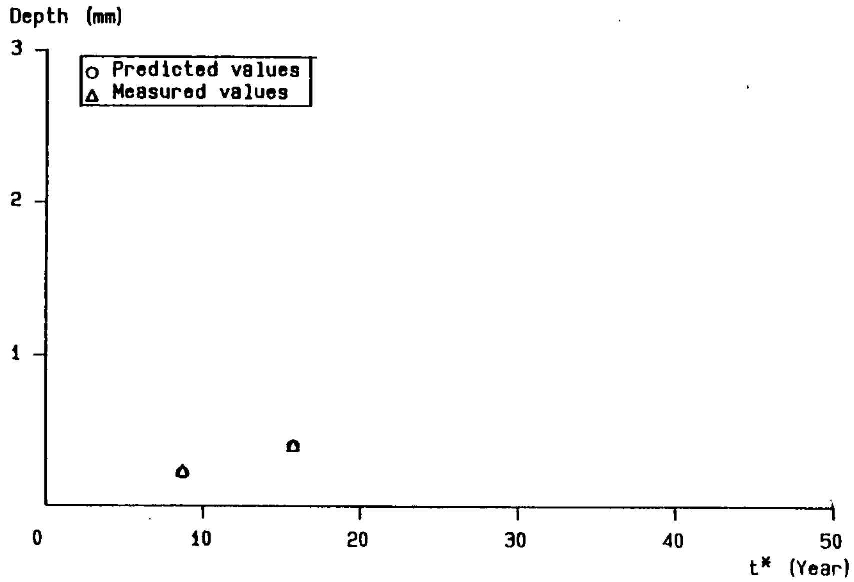

Fig. A5-22 Relation between corrosion depth and exposure time
P22 Middle part of span of main girder (Internal girder)
Expansion joint (Rural and city envi.)
Exposure time = accumulated time after paint life

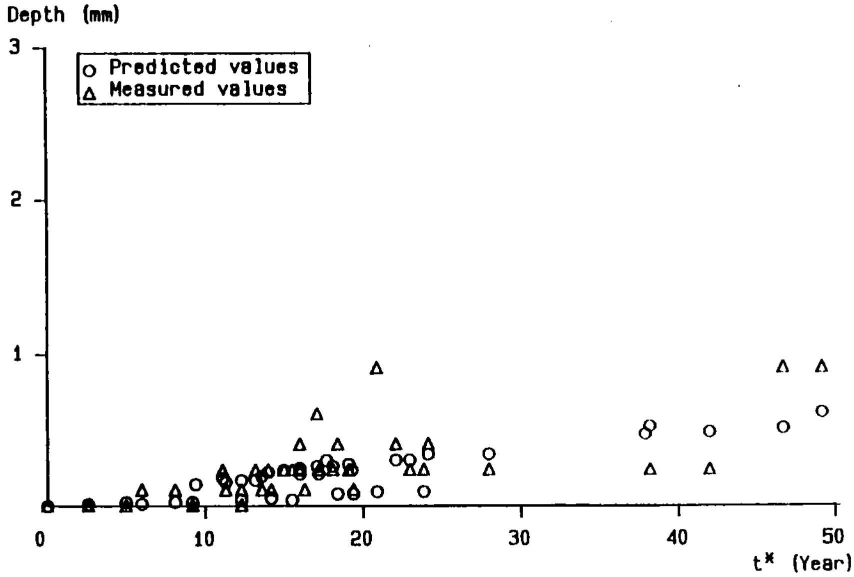

Fig. A5-23 Relation between corrosion depth and exposure time
P23 Middle part of span of main girder (Internal girder)
Lower surface of upper flange (Rural and city envi.)
Exposure time = accumulated time after paint life

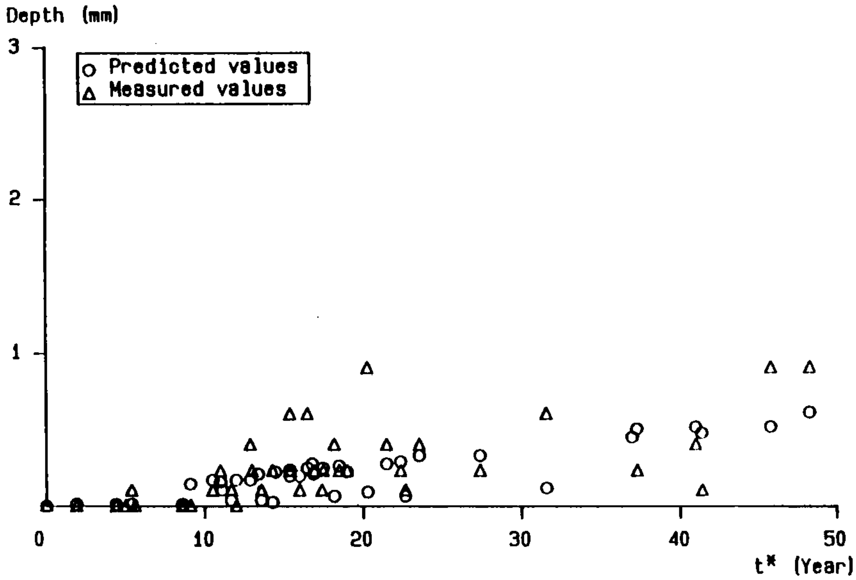

Fig. A5-24 Relation between corrosion depth and exposure time
P24 Middle part of span of main girder (Internal girder)
Web (Rural and city envi.)
Exposure time = accumulated time after paint life

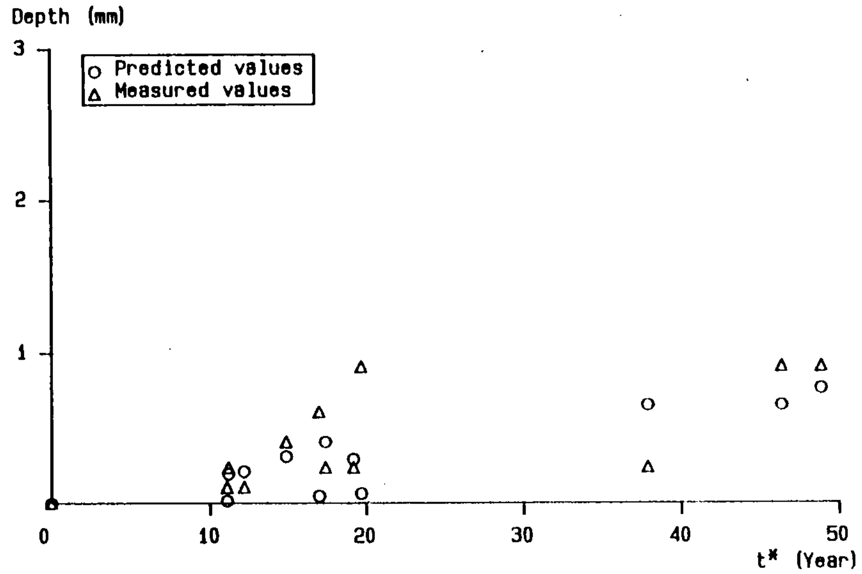

Fig. A5-25 Relation between corrosion depth and exposure time
P25 Middle part of span of main girder (Internal girder)
Upper surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

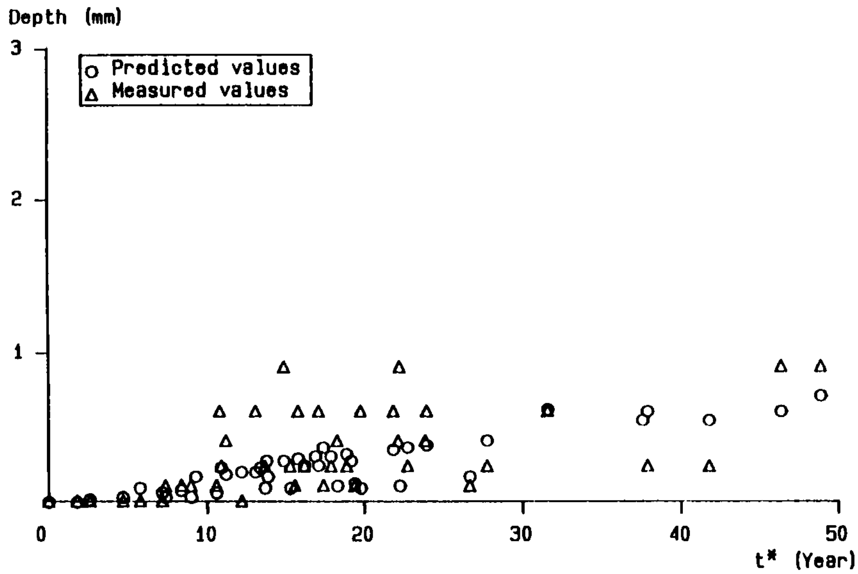

Fig. A5-26 Relation between corrosion depth and exposure time
P26 Middle part of span of main girder (Internal girder)
Lower surface of lower flange (Rural and city envi.)
Exposure time = accumulated time after paint life

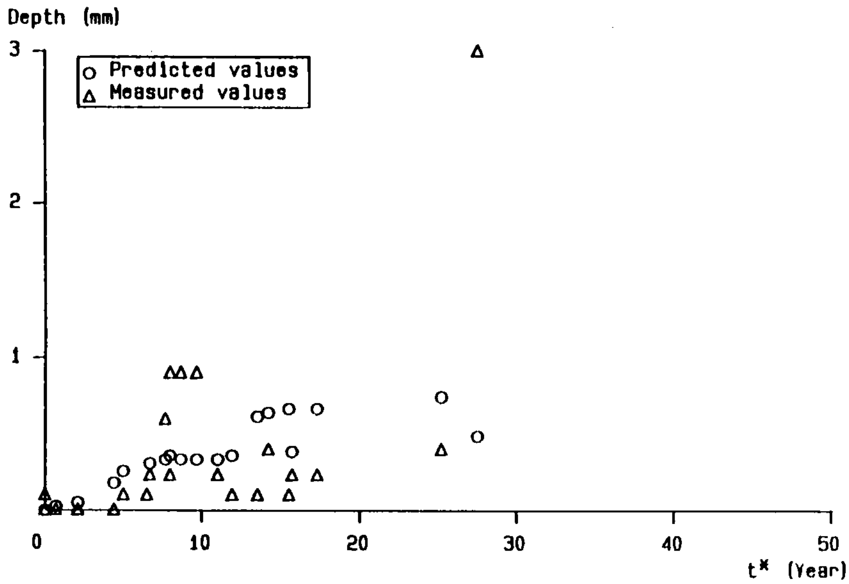

Fig. A6-1 Relation between corrosion depth and exposure time
P1 End part of span of main girder (External girder)
Shoe (Mount. envi.)
Exposure time = accumulated time after paint life

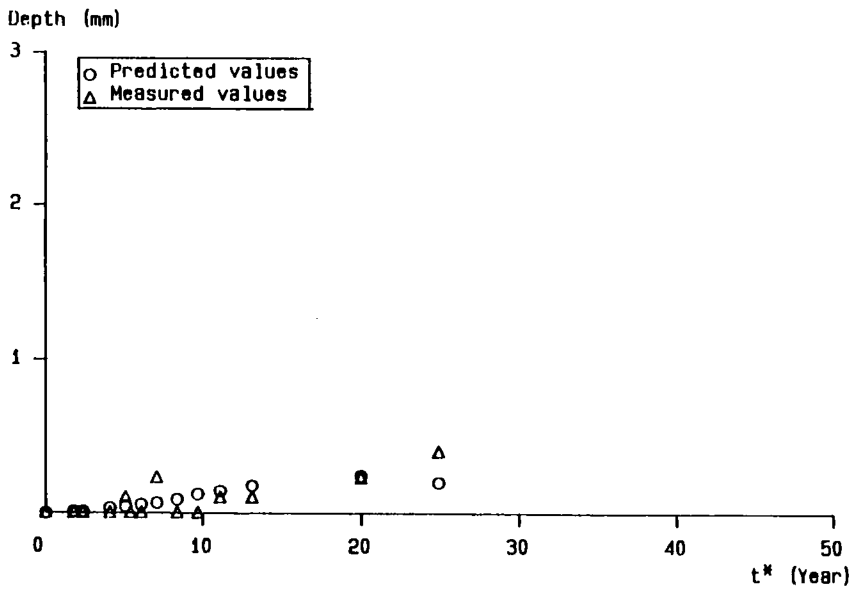

Fig. A6-2 Relation between corrosion depth and exposure time
P2 End part of span of main girder (External girder)
Lower surface of upper flange - Outer side (Mount. envi.)
Exposure time = accumulated time after paint life

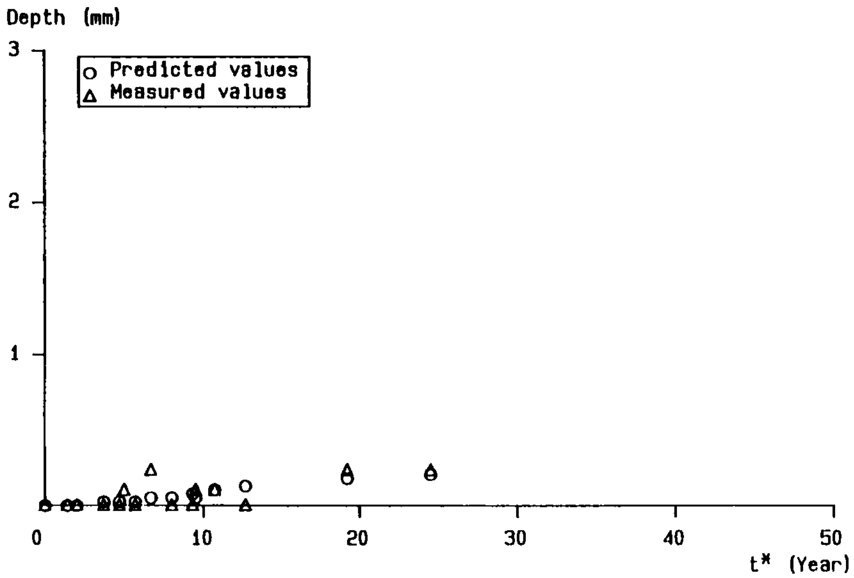

Fig. A6-3 Relation between corrosion depth and exposure time
P3 End part of span of main girder (External girder)
Lower surface of upper flange - Inner side (Mount. envi.)
Exposure time = accumulated time after paint life

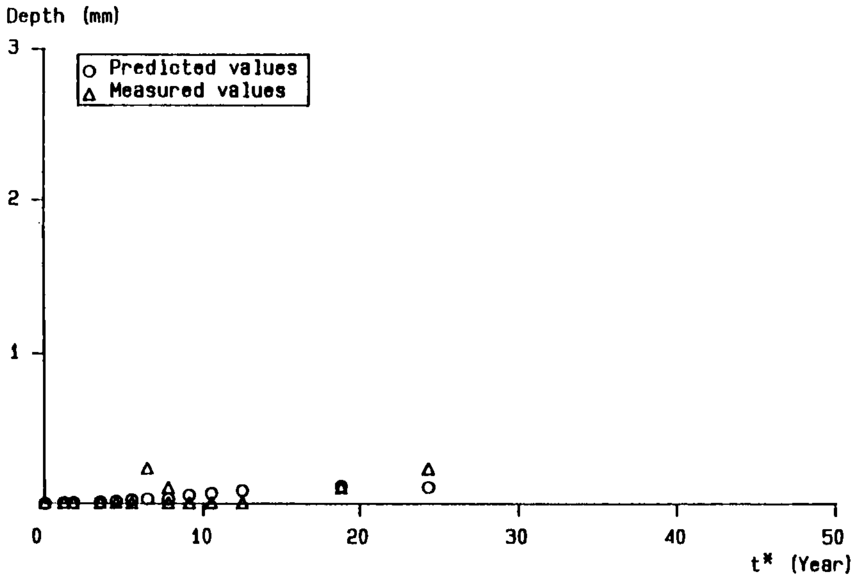

Fig. A6-4 Relation between corrosion depth and exposure time
P4 End part of span of main girder (External girder)
Web - Outer surface (Mount. envi.)
Exposure time = accumulated time after paint life

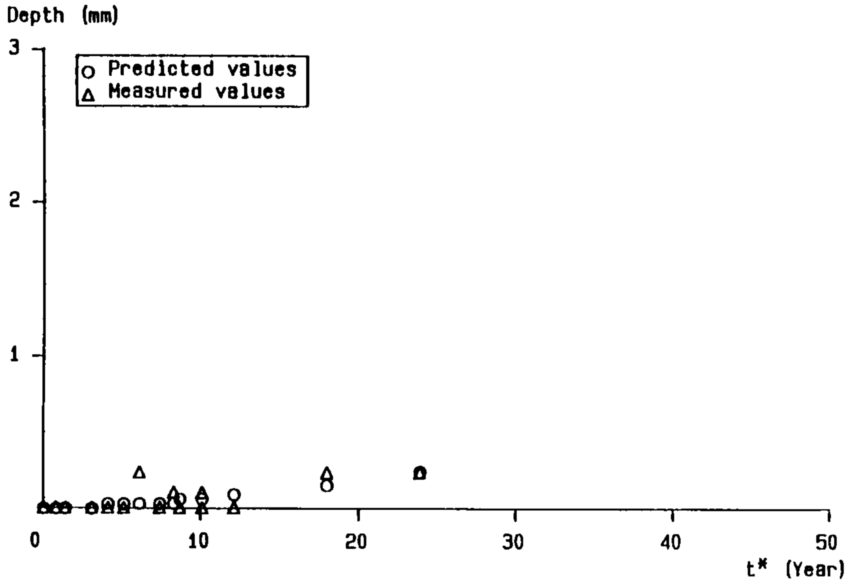

Fig. A6-5 Relation between corrosion depth and exposure time
P5 End part of span of main girder (External girder)
Web - Inner surface (Mount. envi.)
Exposure time = accumulated time after paint life

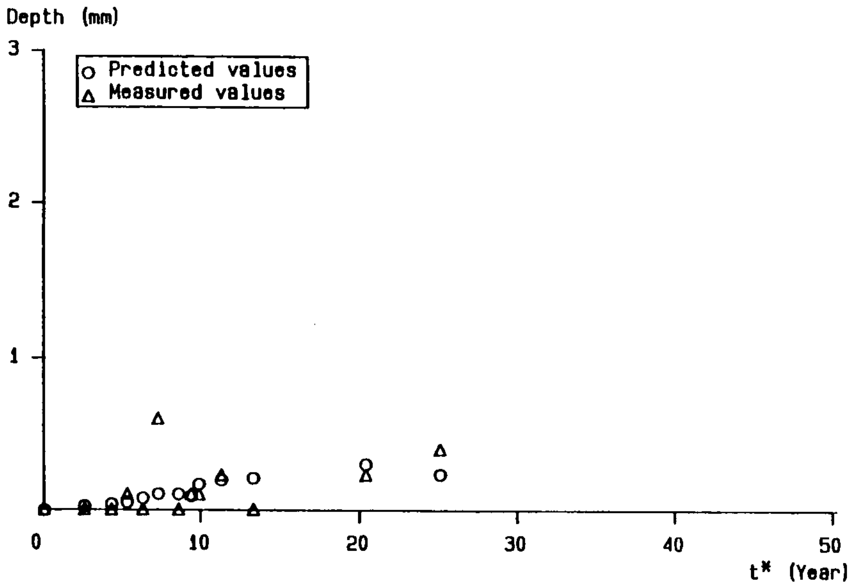

Fig. A6-6 Relation between corrosion depth and exposure time
P6 End part of span of main girder (External girder)
Upper surface of lower flange - Outer side (Mount. envi.)
Exposure time = accumulated time after paint life

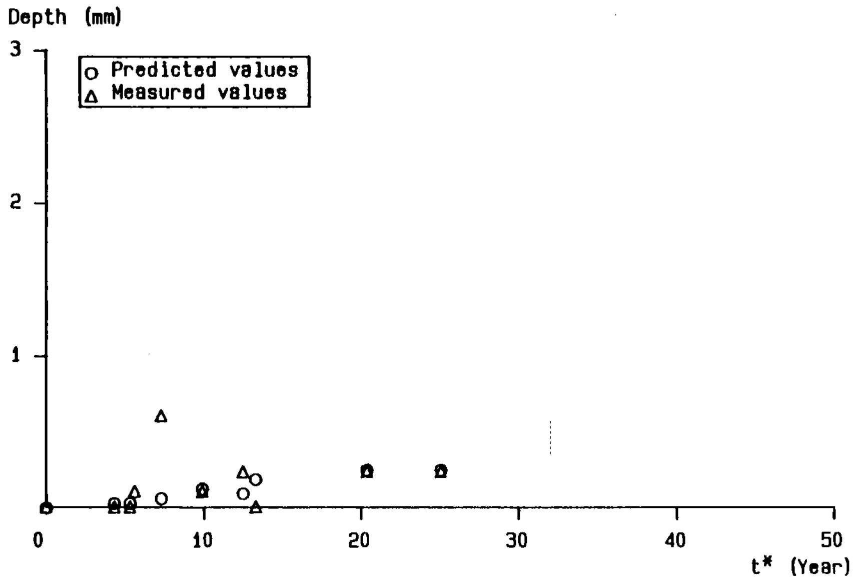

Fig. A6-7 Relation between corrosion depth and exposure time
P7 End part of span of main girder (External girder)
Upper surface of lower flange - Inner side (Mount. envi.)
Exposure time = accumulated time after paint life

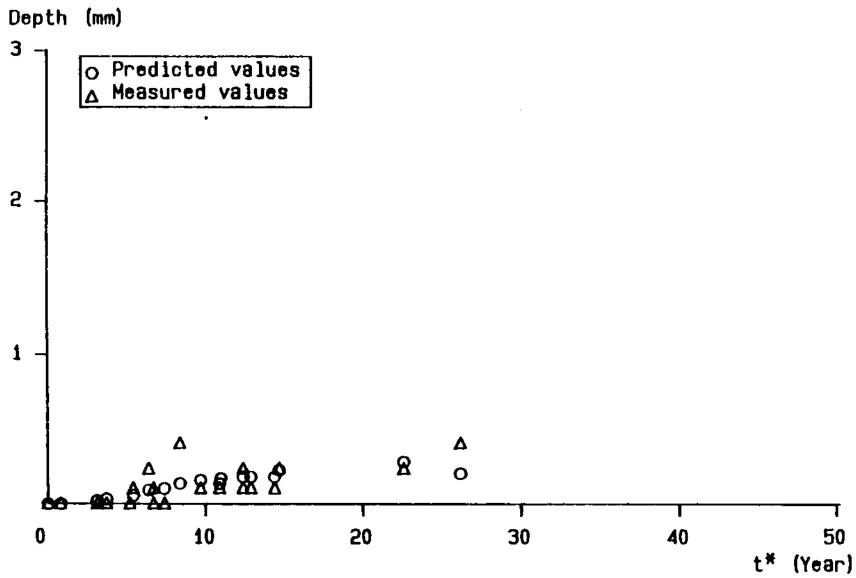

Fig. A6-8 Relation between corrosion depth and exposure time
P8 End part of span of main girder (External girder)
Lower surface of lower flange (Mount. envi.)
Exposure time = accumulated time after paint life

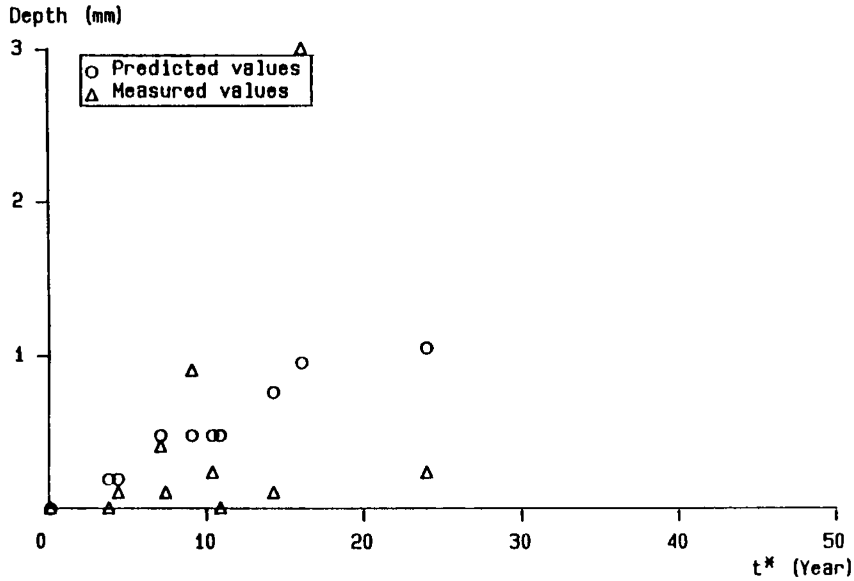

Fig. A6-9 Relation between corrosion depth and exposure time
P9 End part of span of main girder (Internal girder)
Shoe (Mount. envi.)
Exposure time = accumulated time after paint life

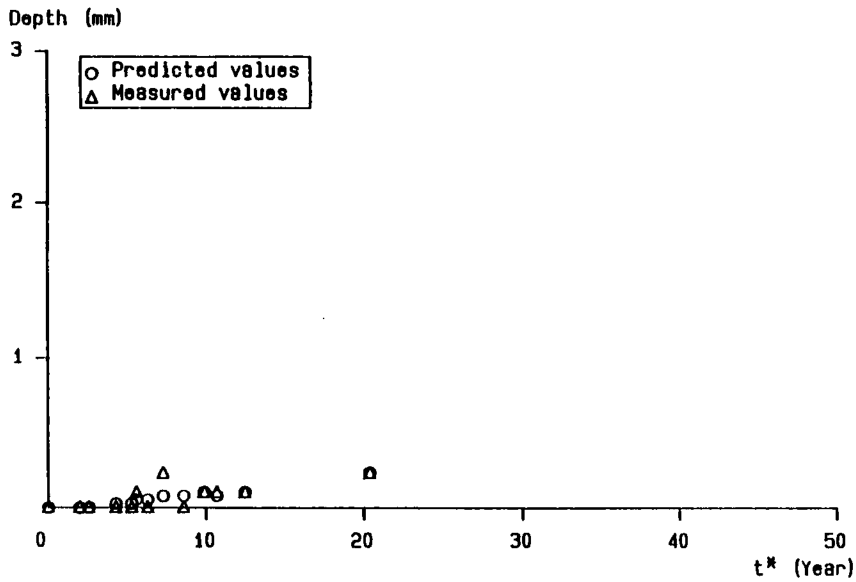

Fig. A6-10 Relation between corrosion depth and exposure time
P10 End part of span of main girder (Internal girder)
Lower surface of upper flange (Mount. envi.)
Exposure time = accumulated time after paint life

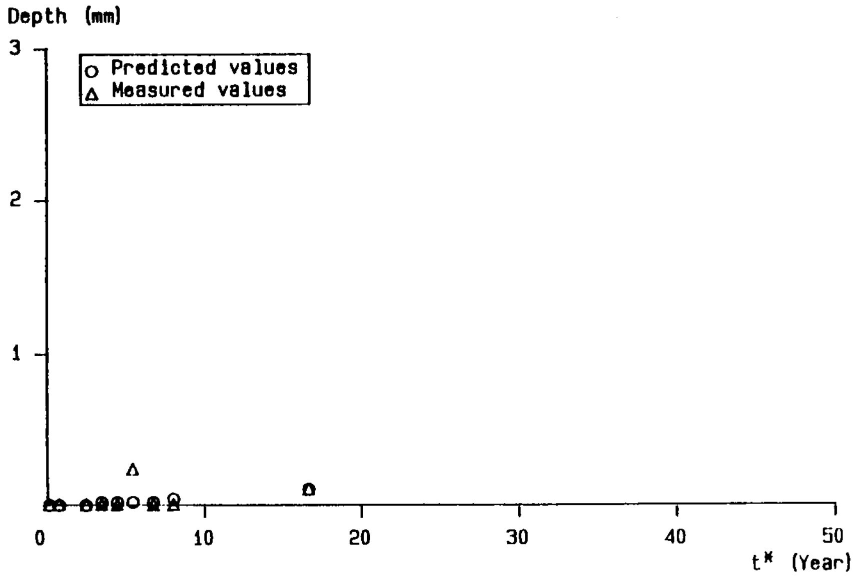

Fig. A6-11 Relation between corrosion depth and exposure time
P11 End part of span of main girder (Internal girder)
Web (Mount. envi.)
Exposure time = accumulated time after paint life

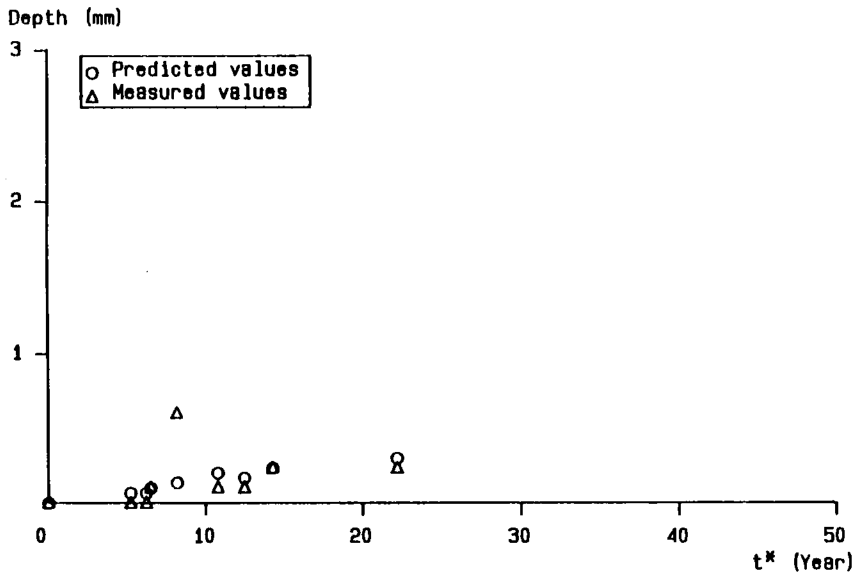

Fig. A6-12 Relation between corrosion depth and exposure time
P12 End part of span of main girder (Internal girder)
Upper surface of lower flange (Mount. envi.)
Exposure time = accumulated time after paint life

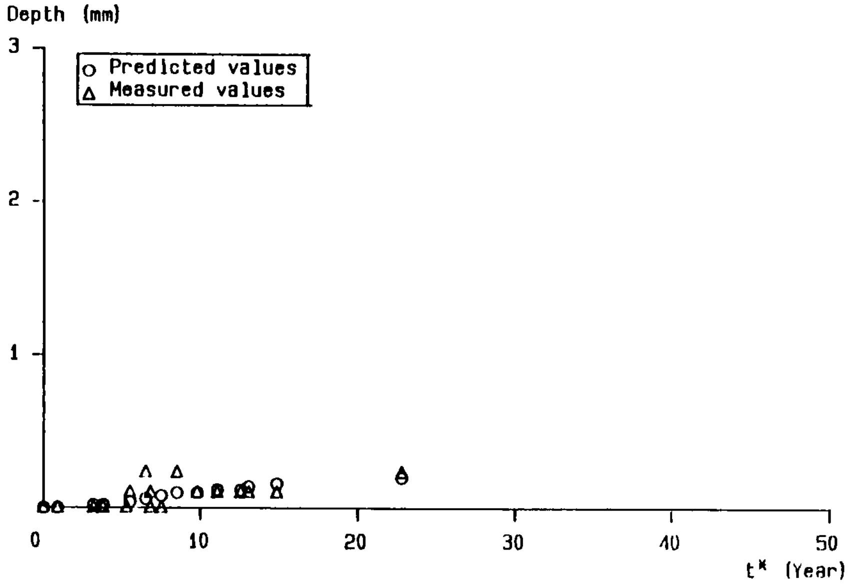

Fig. A6-13 Relation between corrosion depth and exposure time
P13 End part of span of main girder (Internal girder)
Lower surface of lower flange (Mount. envl.)
Exposure time = accumulated time after paint life

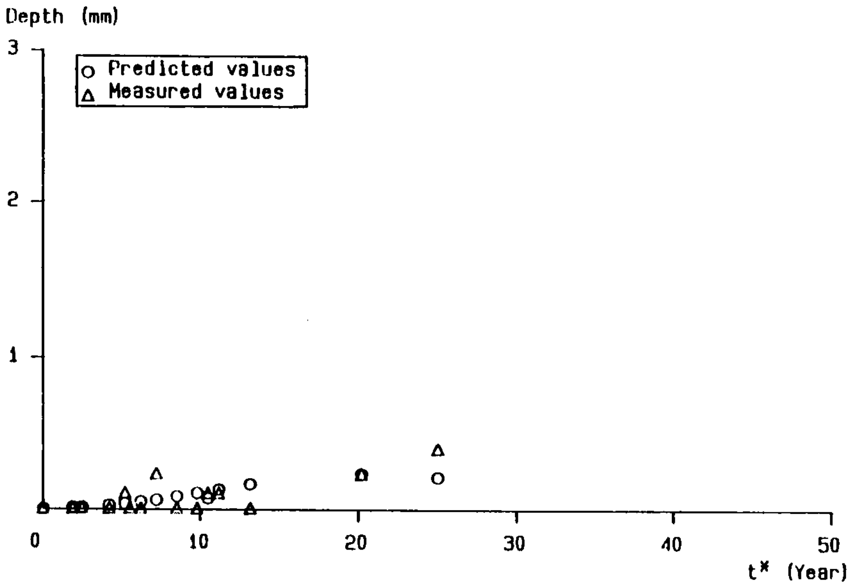

Fig. A6-14 Relation between corrosion depth and exposure time
P15 Middle part of span of main girder (External girder)
Lower surface of upper flange - Outer side (Mount. envl.)
Exposure time = accumulated time after paint life

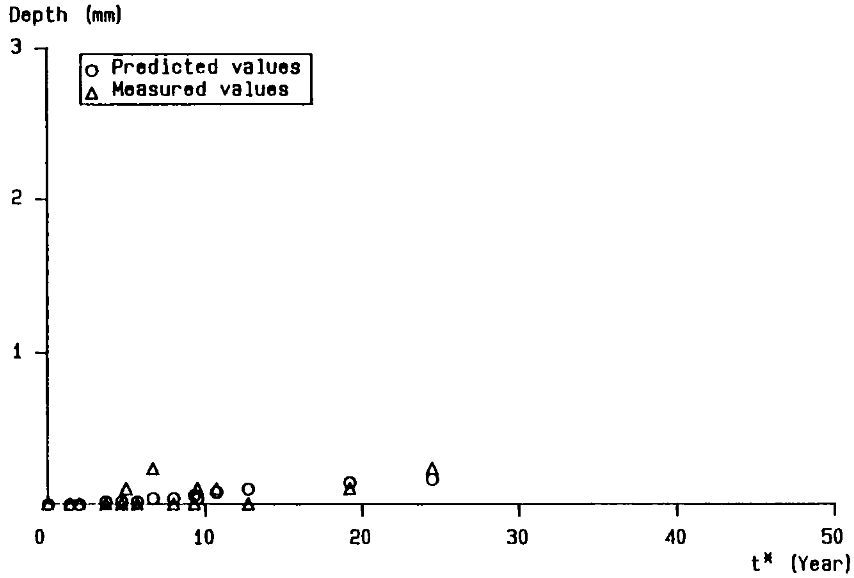

Fig. A6-15 Relation between corrosion depth and exposure time
P16 Middle part of span of main girder (External girder)
Lower surface of upper flange - Inner side (Mount. envi.)
Exposure time = accumulated time after paint life

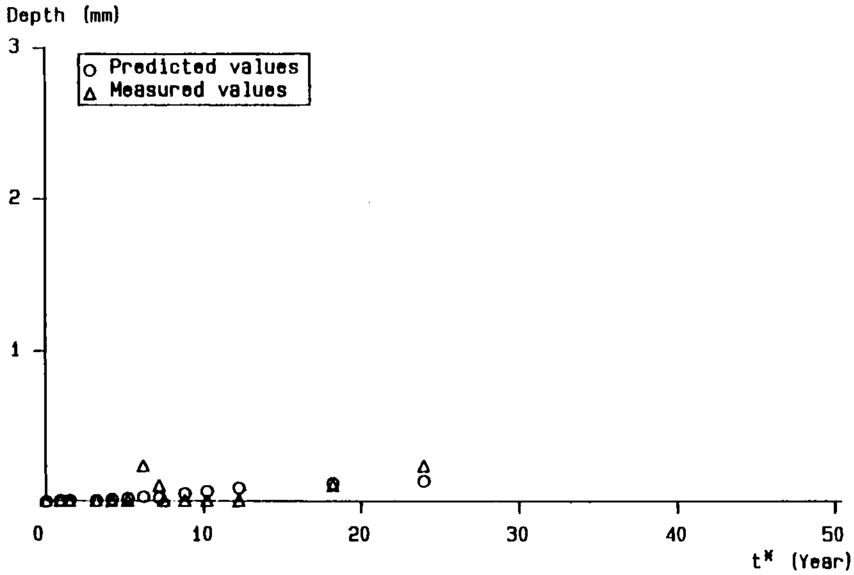

Fig. A6-16 Relation between corrosion depth and exposure time
P17 Middle part of span of main girder (External girder)
Web - Outer surface (Mount. envi.)
Exposure time = accumulated time after paint life

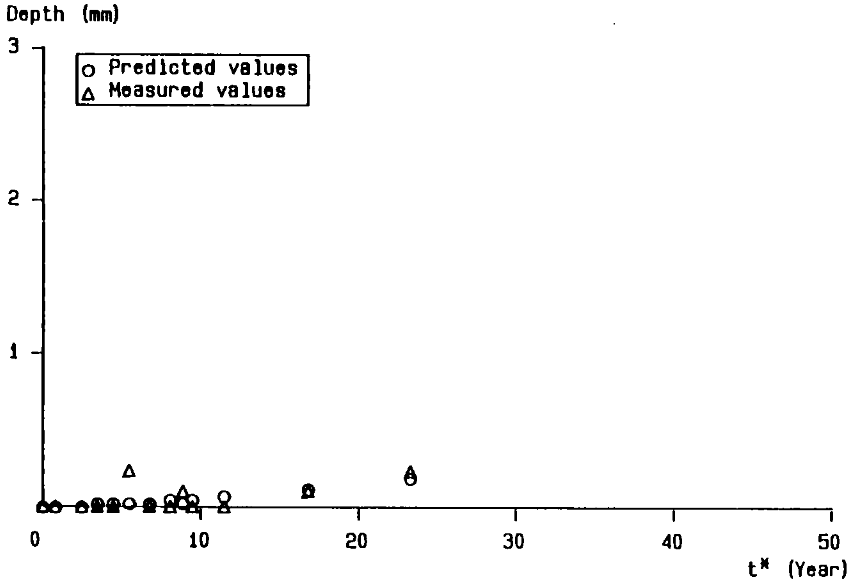

Fig. A6-17 Relation between corrosion depth and exposure time
P18 Middle part of span of main girder (External girder)
Web - Inner surface (Mount. envi.)
Exposure time = accumulated time after paint life

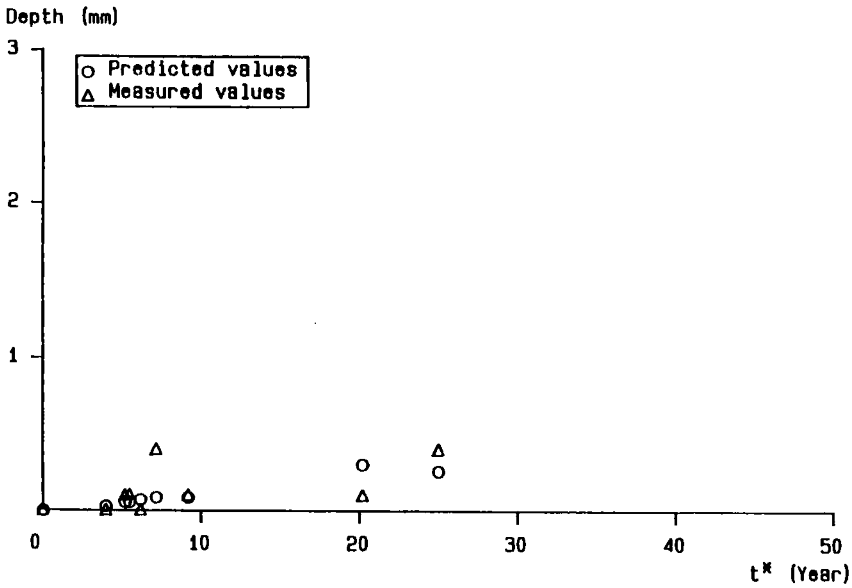

Fig. A6-18 Relation between corrosion depth and exposure time
P19 Middle part of span of main girder (External girder)
Upper surface of lower flange - Outer side (Mount. envi.)
Exposure time = accumulated time after paint life

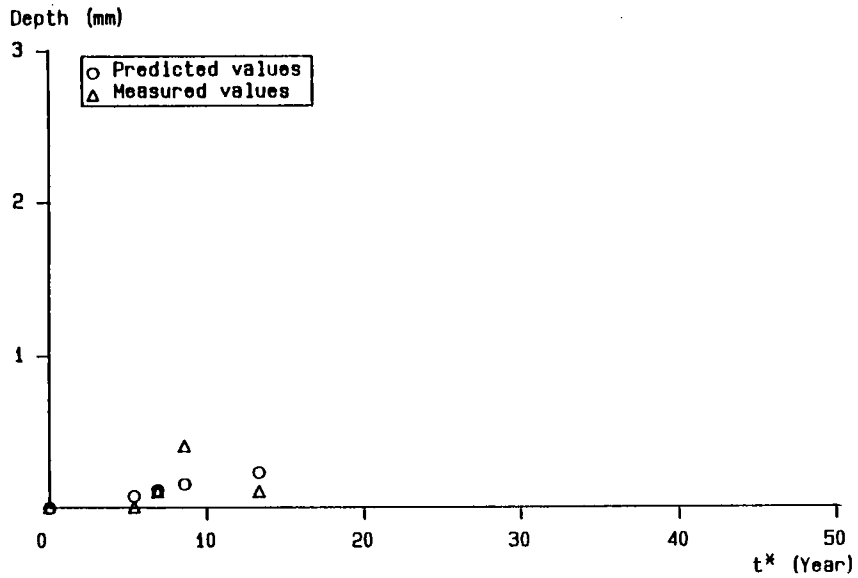

Fig. A6-19 Relation between corrosion depth and exposure time
P20 Middle part of span of main girder (External girder)
Upper surface of lower flange - Inner side (Mount. envi.)
Exposure time = accumulated time after paint life

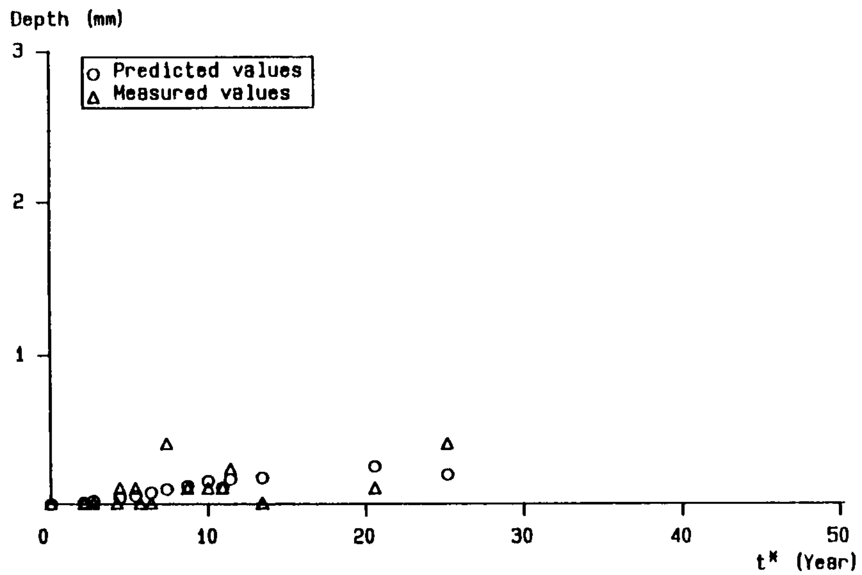

Fig. A6-20 Relation between corrosion depth and exposure time
P21 Middle part of span of main girder (External girder)
Lower surface of lower flange (Mount. envi.)
Exposure time = accumulated time after paint life

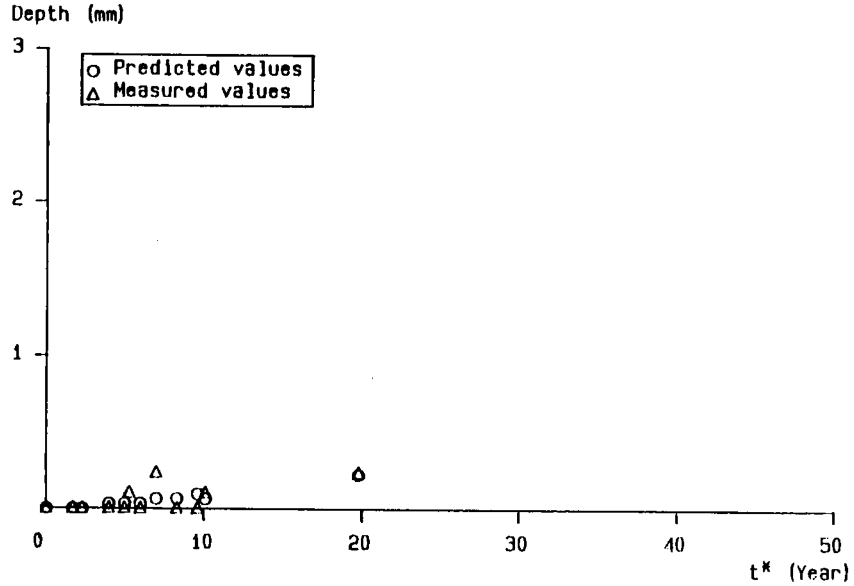

Fig. A6-21 Relation between corrosion depth and exposure time
P23 Middle part of span of main girder (Internal girder)
Lower surface of upper flange (Mount. envi.)
Exposure time = accumulated time after paint life

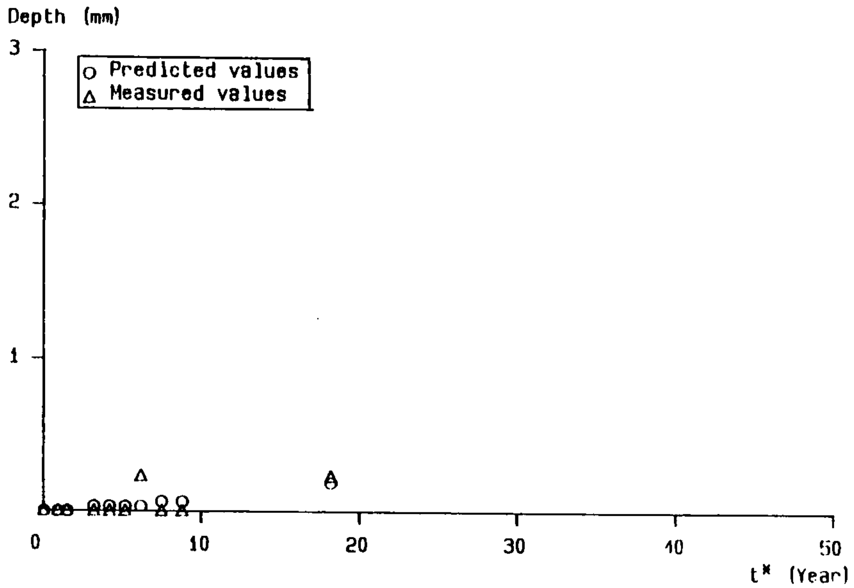

Fig. A6-22 Relation between corrosion depth and exposure time
P24 Middle part of span of main girder (Internal girder)
Web (Mount. envi.)
Exposure time = accumulated time after paint life

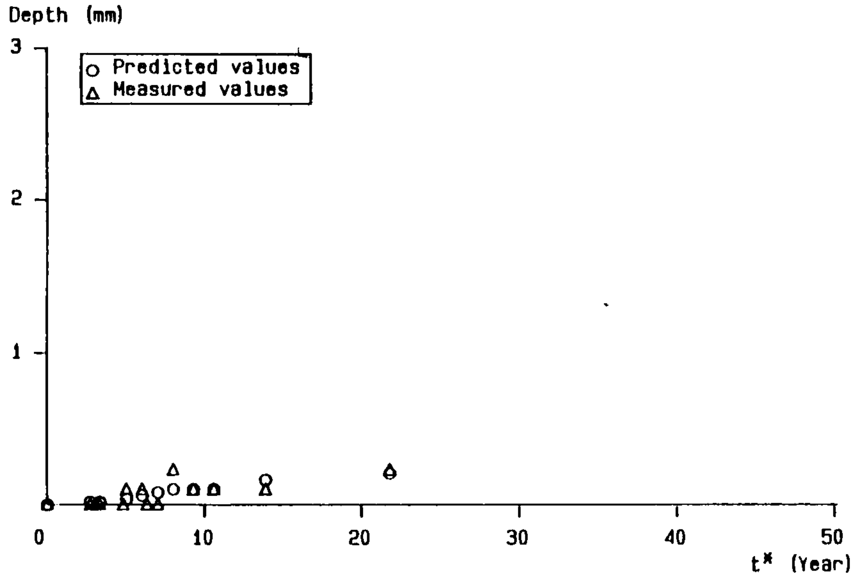

Fig. A6-23 Relation between corrosion depth and exposure time
P26 Middle part of span of main girder (Internal girder)
Lower surface of lower flange (Mount. envi.)
Exposure time = accumulated time after paint life

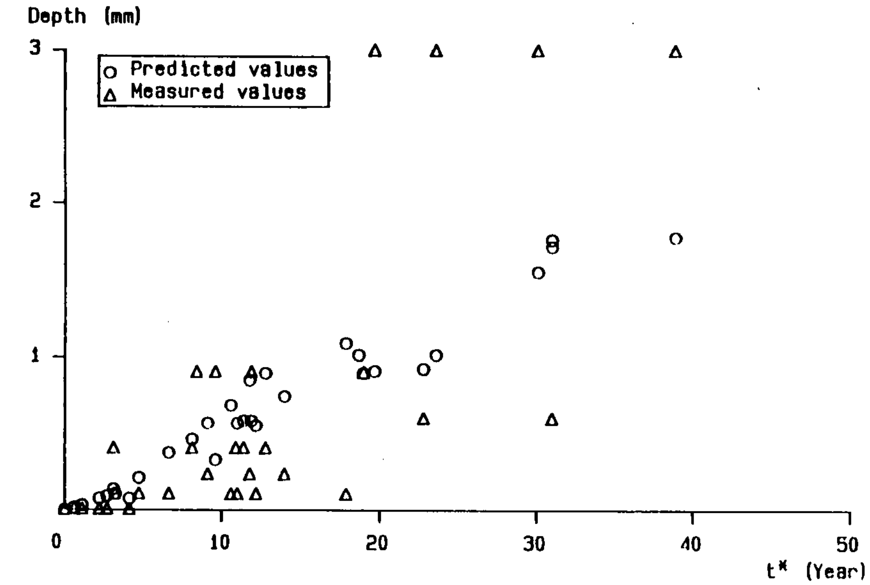

Fig. A7-1 Relation between corrosion depth and exposure time
P1 End part of span of main girder (External girder)
Shoe (Marine envi.)
Exposure time = accumulated time after paint life

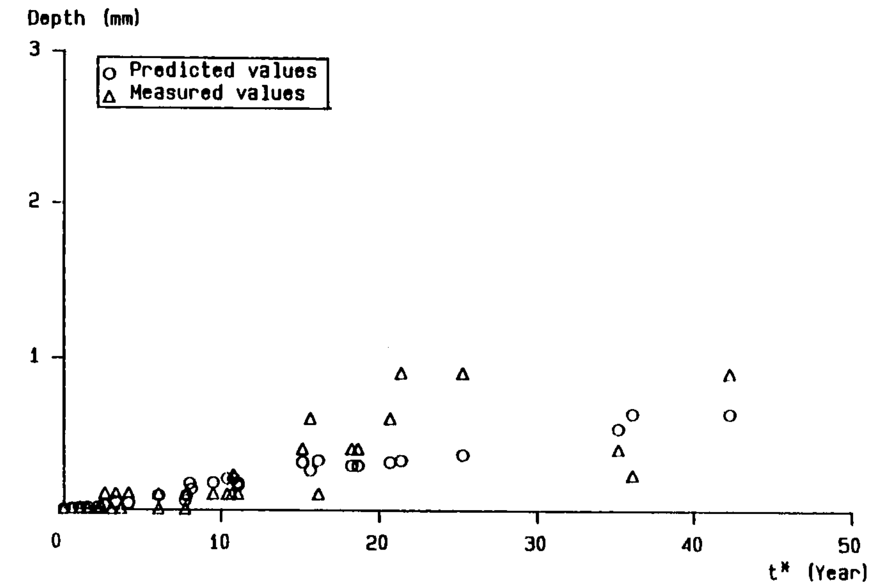

Fig. A7-2 Relation between corrosion depth and exposure time
P2 End part of span of main girder (External girder)
Lower surface of upper flange - Outer side (Marine envi.)
Exposure time = accumulated time after paint life

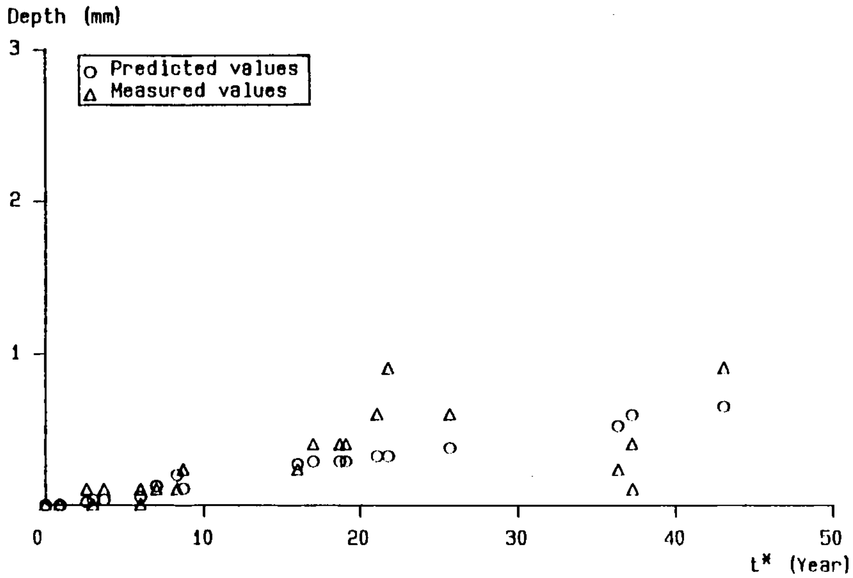

Fig. A7-3 Relation between corrosion depth and exposure time
P3 End part of span of main girder (External girder)
Lower surface of upper flange - Inner side (Marine envi.)
Exposure time = accumulated time after paint life

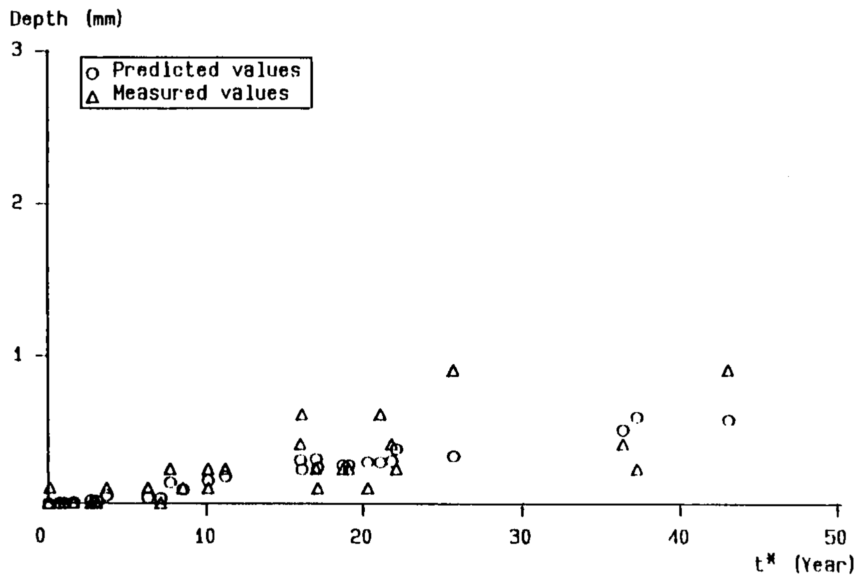

Fig. A7-4 Relation between corrosion depth and exposure time
P4 End part of span of main girder (External girder)
Web - Outer surface (Marine envi.)
Exposure time = accumulated time after paint life

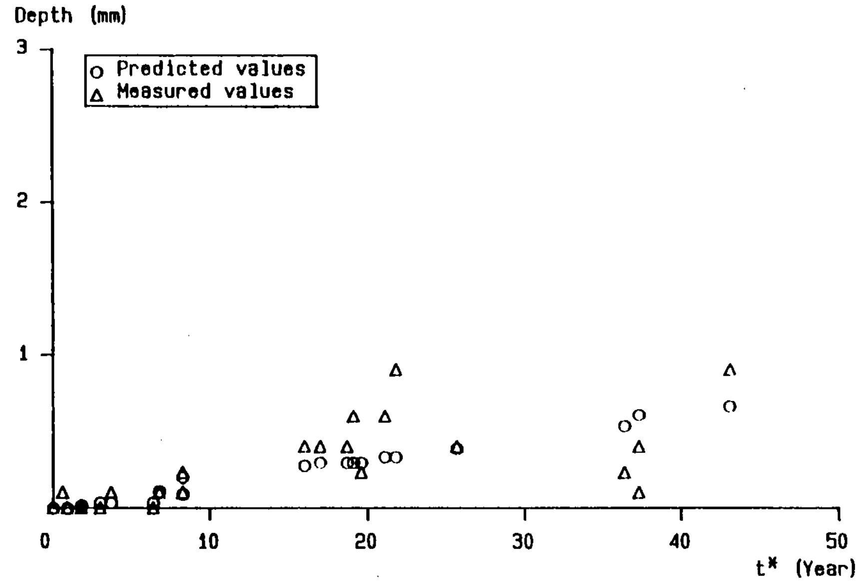

Fig. A7-5 Relation between corrosion depth and exposure time
P5 End part of span of main girder (External girder)
Web - Inner surface (Marine envi.)
Exposure time = accumulated time after paint life

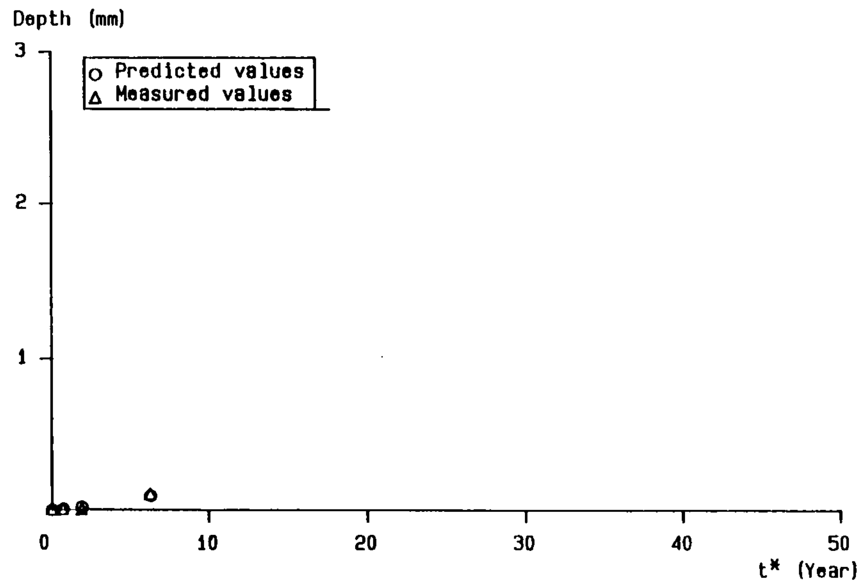

Fig. A7-6 Relation between corrosion depth and exposure time
P6 End part of span of main girder (External girder)
Upper surface of lower flange - Outer side (Marine envi.)
Exposure time = accumulated time after paint life

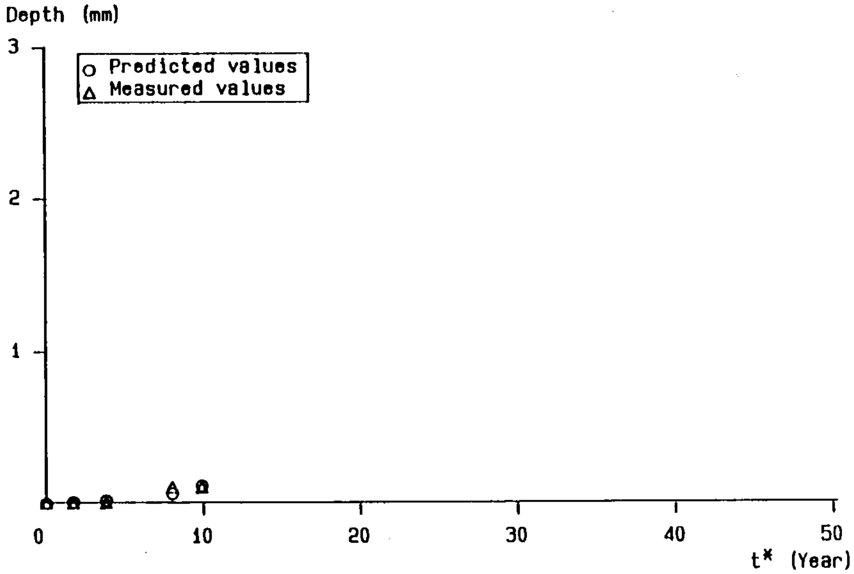

Fig. A7-7 Relation between corrosion depth and exposure time
P7 End part of span of main girder (External girder)
Upper surface of lower flange - Inner side (Marine envi.)
Exposure time = accumulated time after paint life

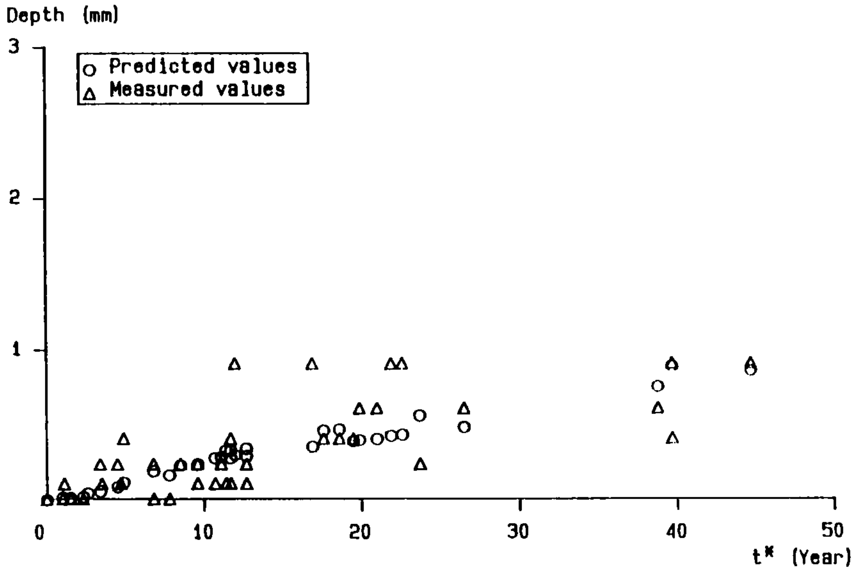

Fig. A7-8 Relation between corrosion depth and exposure time
P8 End part of span of main girder (External girder)
Lower surface of lower flange (Marine envi.)
Exposure time = accumulated time after paint life

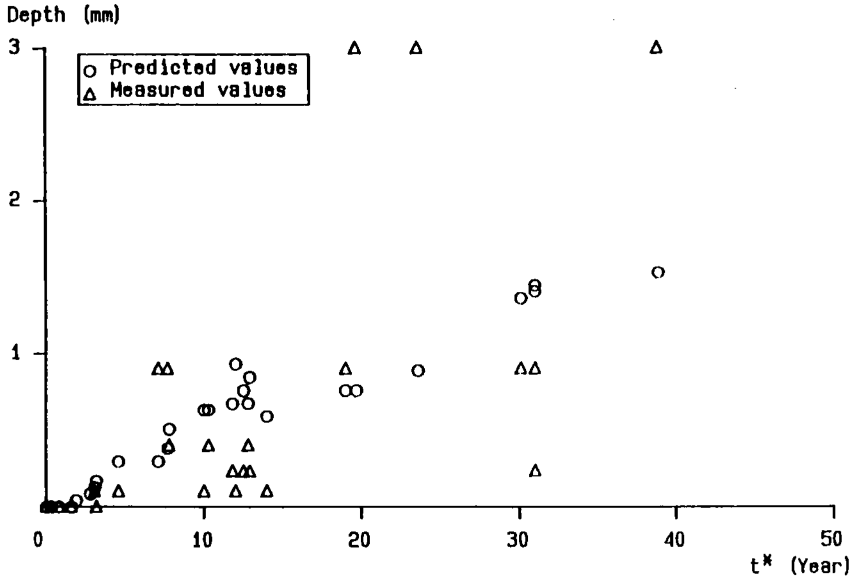

Fig. A7-9 Relation between corrosion depth and exposure time
P9 End part of span of main girder (Internal girder)
Shoe (Marine envi.)
Exposure time = accumulated time after paint life

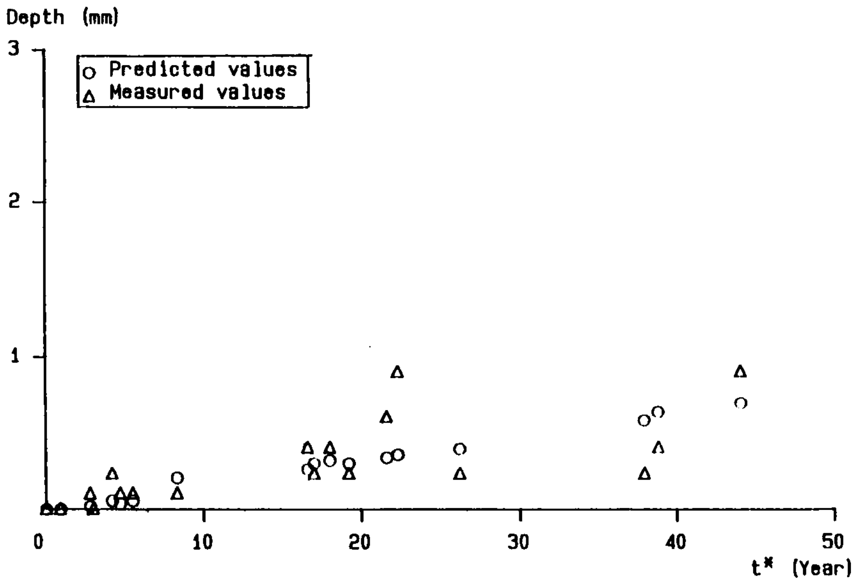

Fig. A7-10 Relation between corrosion depth and exposure time
P10 End part of span of main girder (Internal girder)
Lower surface of upper flange (Marine envi.)
Exposure time = accumulated time after paint life

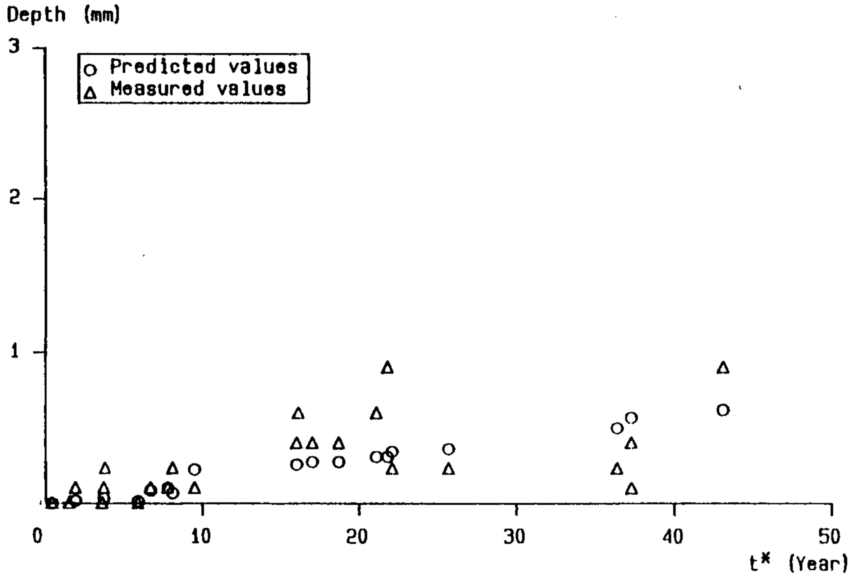

Fig. A7-11 Relation between corrosion depth and exposure time
P11 End part of span of main girder (Internal girder)
Web (Marine envi.)
Exposure time = accumulated time after paint life

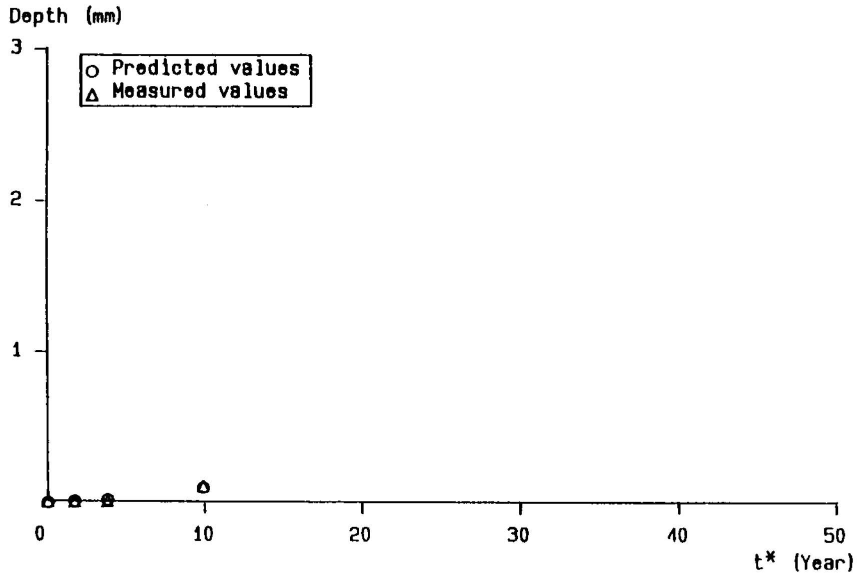

Fig. A7-12 Relation between corrosion depth and exposure time
P12 End part of span of main girder (Internal girder)
Upper surface of lower flange (Marine envi.)
Exposure time = accumulated time after paint life

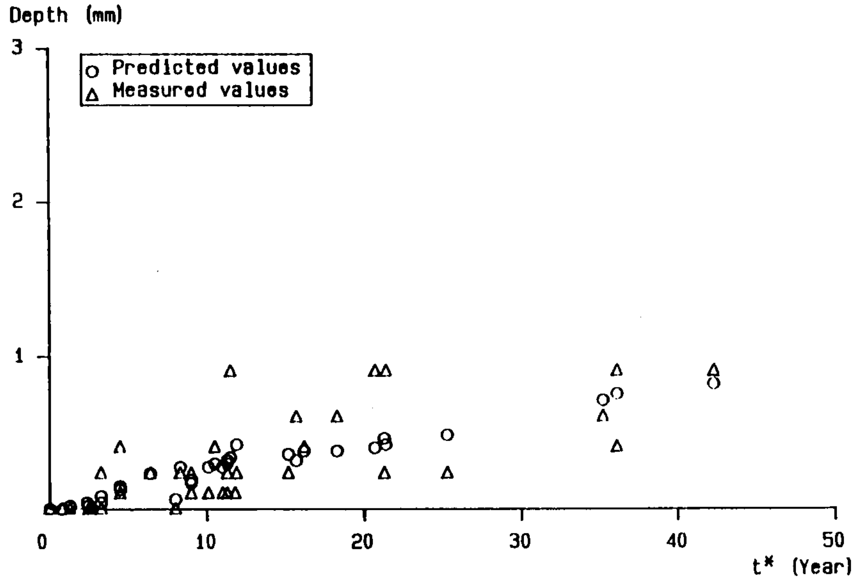

Fig. A7-13 Relation between corrosion depth and exposure time
P13 End part of span of main girder (Internal girder)
Lower surface of lower flange (Marine envi.)
Exposure time = accumulated time after paint life

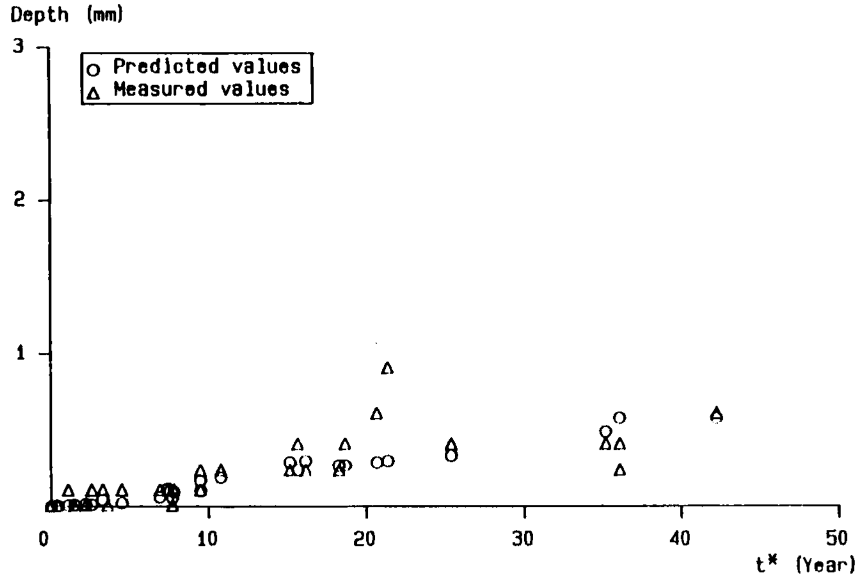

Fig. A7-14 Relation between corrosion depth and exposure time
P15 Middle part of span of main girder (External girder)
Lower surface of upper flange - Outer side (Marine envi.)
Exposure time = accumulated time after paint life

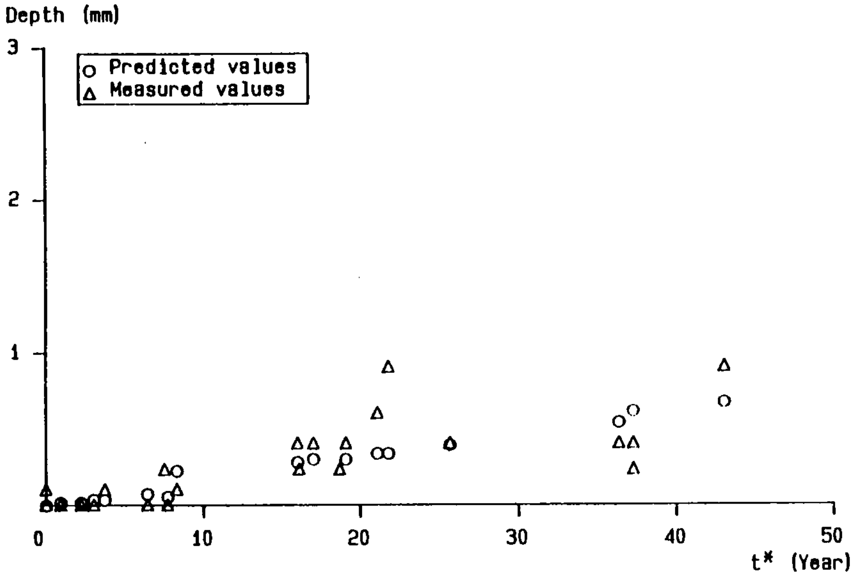

Fig. A7-15 Relation between corrosion depth and exposure time
P16 Middle part of span of main girder (External girder)
Lower surface of upper flange - Inner side (Marine envi.)
Exposure time = accumulated time after paint life

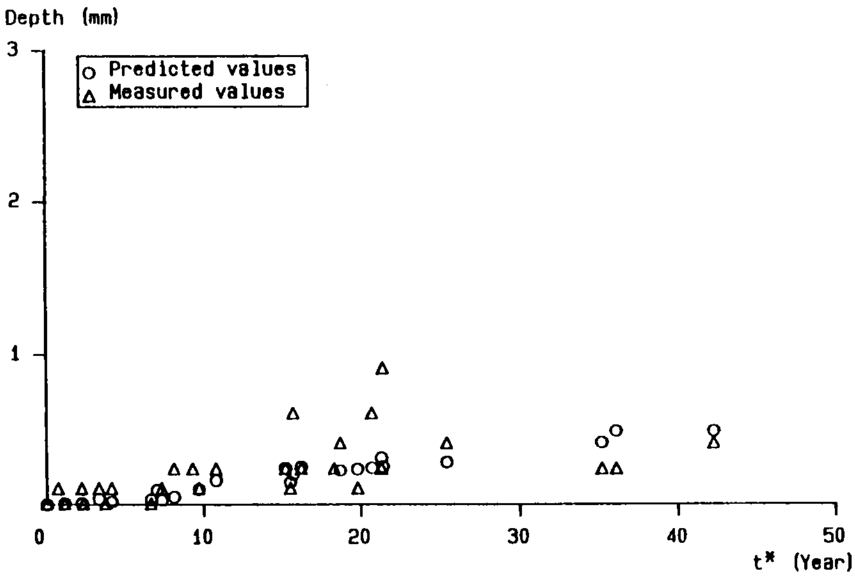

Fig. A7-16 Relation between corrosion depth and exposure time
P17 Middle part of span of main girder (External girder)
Web - Outer surface (Marine envi.)
Exposure time = accumulated time after paint life

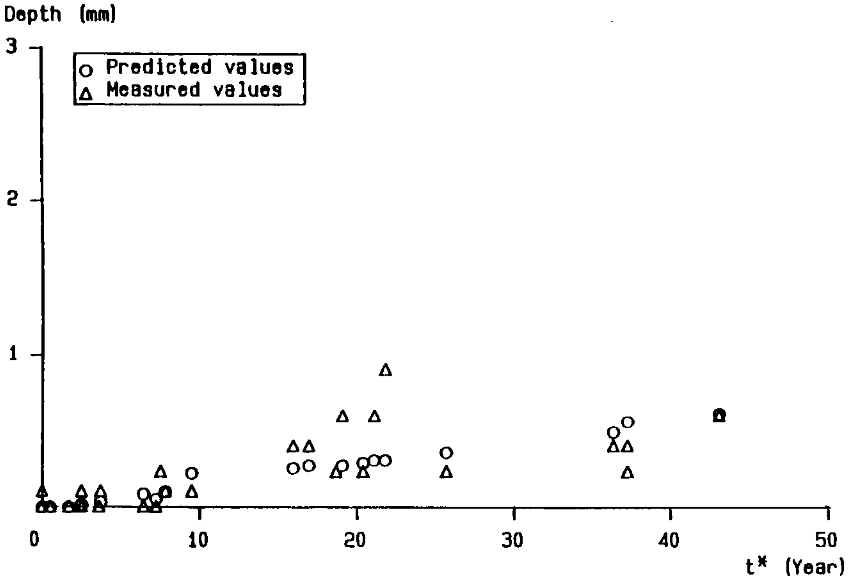

Fig. A7-17 Relation between corrosion depth and exposure time
P18 Middle part of span of main girder (External girder)
Web - Inner surface (Marine envi.)
Exposure time = accumulated time after paint life

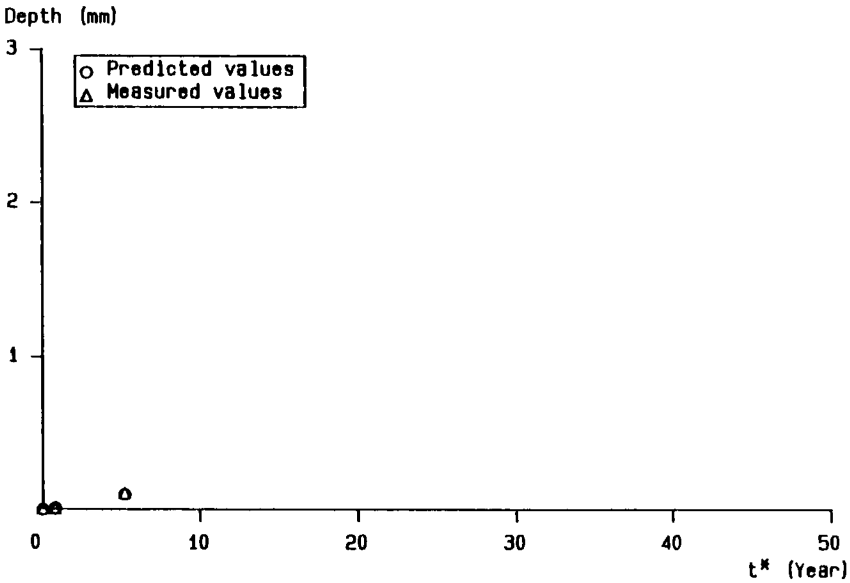

Fig. A7-18 Relation between corrosion depth and exposure time
P19 Middle part of span of main girder (External girder)
Upper surface of lower flange - Outer side (Marine envi.)
Exposure time = accumulated time after paint life

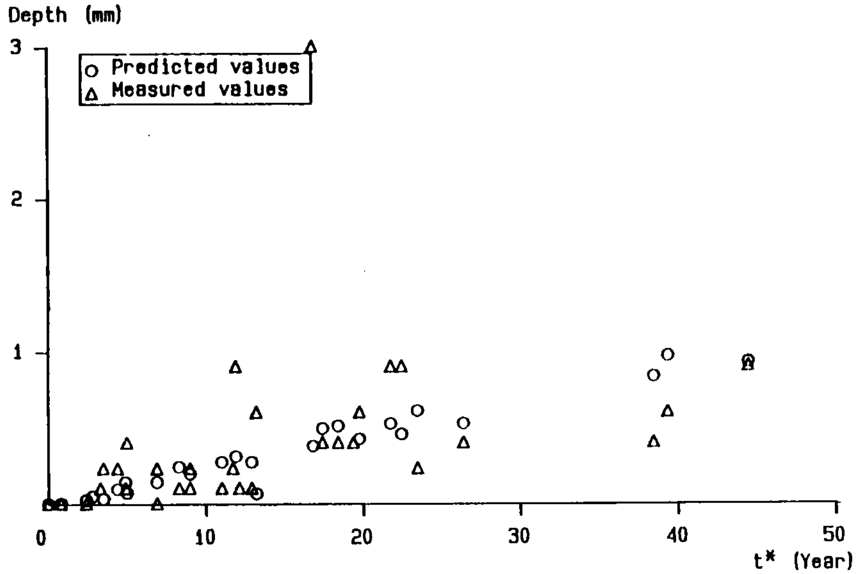

Fig. A7-19 Relation between corrosion depth and exposure time
P21 Middle part of span of main girder (External girder)
Lower surface of lower flange (Marine envi.)
Exposure time = accumulated time after paint life

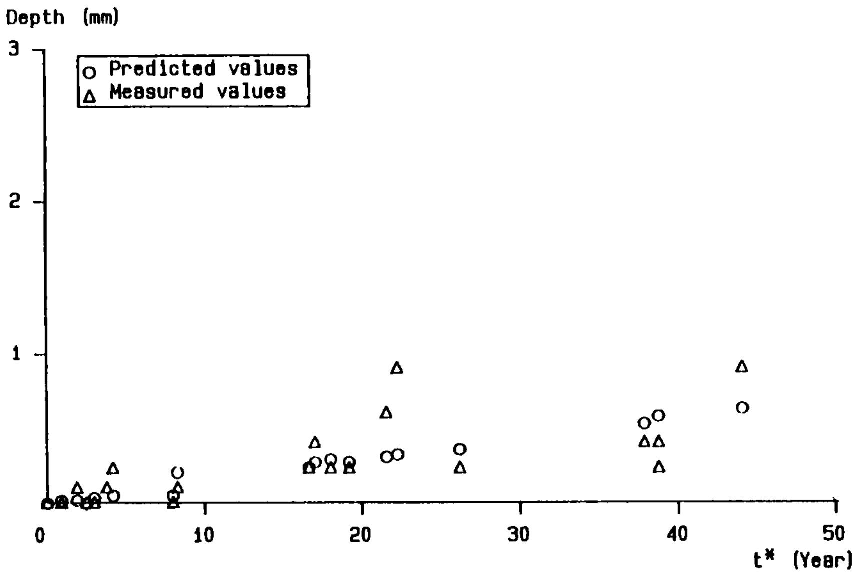

Fig. A7-20 Relation between corrosion depth and exposure time
P23 Middle part of span of main girder (Internal girder)
Lower surface of upper flange (Marine envi.)
Exposure time = accumulated time after paint life

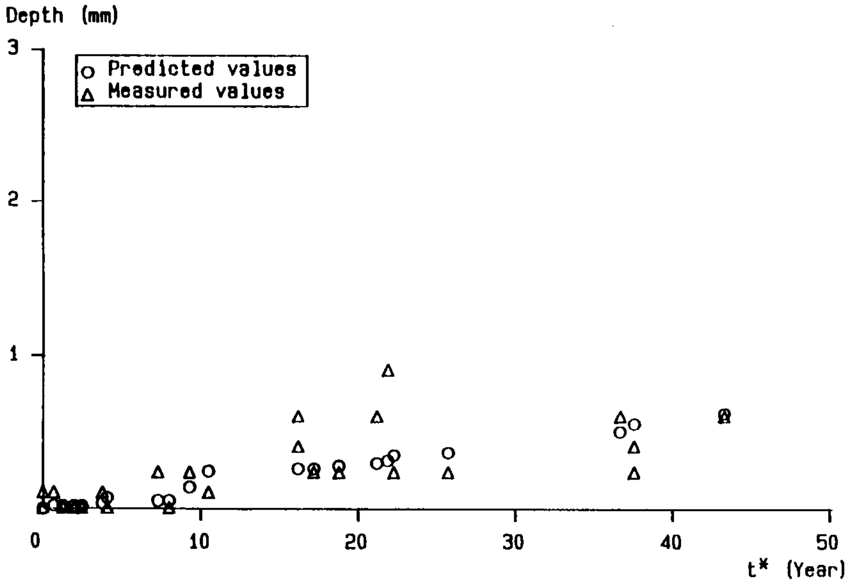

Fig. A7-21 Relation between corrosion depth and exposure time
P24 Middle part of span of main girder (Internal girder)
Web (Marine envi.)
Exposure time = accumulated time after paint life

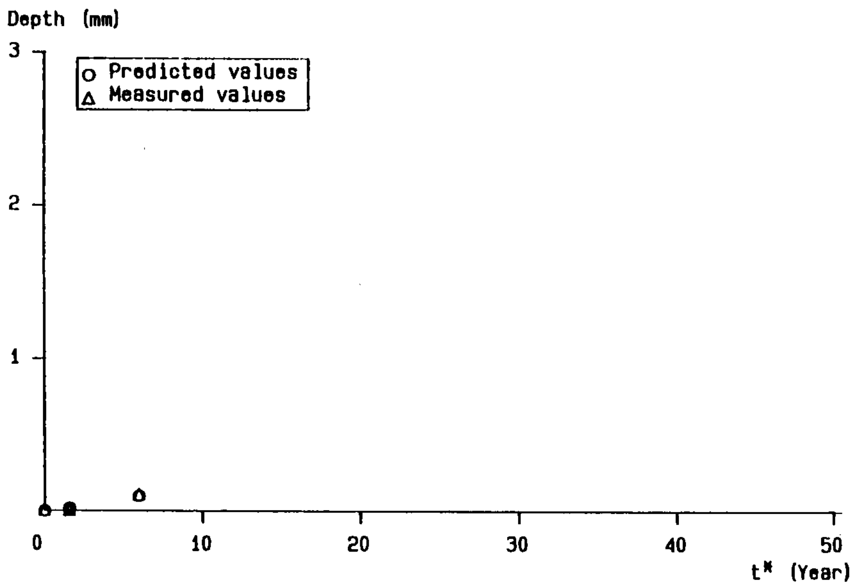

Fig. A7-22 Relation between corrosion depth and exposure time
P25 Middle part of span of main girder (Internal girder)
Upper surface of lower flange (Marine envi.)
Exposure time = accumulated time after paint life

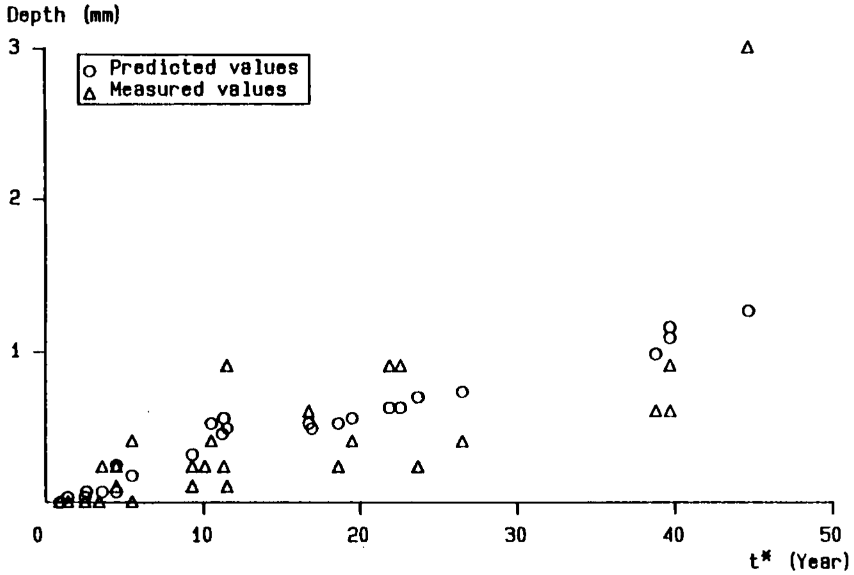

Fig. A7-23 Relation between corrosion depth and exposure time
P26 Middle part of span of main girder (Internal girder)
Lower surface of lower flange (Marine envi.)
Exposure time = accumulated time after paint life